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March 29-31, 1978
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Attendance at the two and one-half day Symposium was approximately 170 with good representation by industry, universities, consulting firms, as well as state and Federal agencies.

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INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods by used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The Ninth National Symposium on Food Processing Wastes was co-sponsored with the National Food Prodessors Association, American Meat Institute, Southeastern Poultry and Egg Association, Western States Meat Packers Association, Pacific Egg and Poultry Association and the American Society of Agricultural Engineets. The primary purpose of these symposia is the dissemination of the latest research, development, and demonstration information of process modifications waste treatment, by-product recovery and water reuse to industry, consultants and government personnel. Twenty-four papers are included in this Proceedings as well as the final registration list. For more information contact the Food and Wood Products Branch of the Industrial Pollution Control Division.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The Proceedings contains copies of the 24 papers presented at the Ninth National Symposium on Food Processing Wastes. Subjects included: processing modifications product and by-product recovery, wastewater treatment, water recycle and water reuse for several segments of the food processing industry. These segments included: red meat and poultry, seafood, dairy, fruit, and vegetable.

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A SUMMARY OF COLD CLIMATE OPERATING EXPERIENCES WITH BIOLOGICAL WASTE TREATMENT SYSTEMS IN THE FOOD PROCESSING INDUSTRY

by

C. W. Fulton*, P. A. Mulyk*, and J. Haskill**

INTRODUCTION

Food processing operations are a source of highly concentrated organic wastewater which is amenable to stabilization by biological treatment. A wide variety of biological processes are available and have been employed by the Industry in an attempt to provide the necessary treatment. While many treatment systems have been very successful, others have encountered severe operating problems and performance has not always met Industry's and regulatory agencies' expectations. This has been particularly true in northern regions, where cold climates impose an additional hardship on the operation of biological systems.

As part of a project conducted for the Food and Allied Industries, Abatement and Compliance Branch of the Water Pollution Control Directorate of Fisheries and Environment Canada, Stanley Associates Engineering Ltd. conducted site visits to a number of food processing plants in Canada and the northern United States. The objective of these visits was to obtain operating and performance data on biological waste treatment systems utilized by the Industry, and to discuss the problems being encountered in their operation.

Plant visits were restricted to those facilities which were considered by local or Federal regulatory agencies to exemplify best practicable technology for the Industry.

This paper presents case histories of twelve such plants, outlining their design criteria, loading rates, treatment efficiencies, operating experience, and capital and operating costs. The case histories presented cover the sectors of the food processing industry outlined below:

---

*Stanley Associates Engineering Ltd., Calgary, Alberta
**Food and Allied Industries, Water Pollution Control Directorate, Fisheries and Environment Canada, Ottawa, Ontario

1) Meat and Poultry Processing: 2 poultry plants
   3 red meat plants

2) Dairy and Milk Processing: 3 plants

3) Fruit and Vegetable Processing: 1 potato plant
   1 fruit juice plant

4) Beverage Industry: 1 distillery

5) Fish Processing: 1 plant.

COST DATA

Difficulty was encountered in gathering reliable information on capital and operating costs for the majority of plants visited. In some cases, the information simply did not exist. Where data on the capital cost of treatment facilities was provided, this has been updated to a November 1977 value, using an Engineering News Record Construction Cost Index of 2660.

Where possible, actual operating costs reported by the plants have been presented. However, in the majority of cases, such data did not exist. As a result, operating costs for these plants have been estimated on the basis of the manpower and electrical requirements of the facility, as reported by plant personnel. A standard value of $10/hour for manpower costs and 2.5¢/kW-hr for electrical power has been used in calculating operating costs, and to facilitate comparisons between plants. The manpower cost is based on the average 1977 wage rate in the Canadian construction industry, while the energy cost represents the average electric power cost at municipal sewage treatment plants in Alberta in 1977.

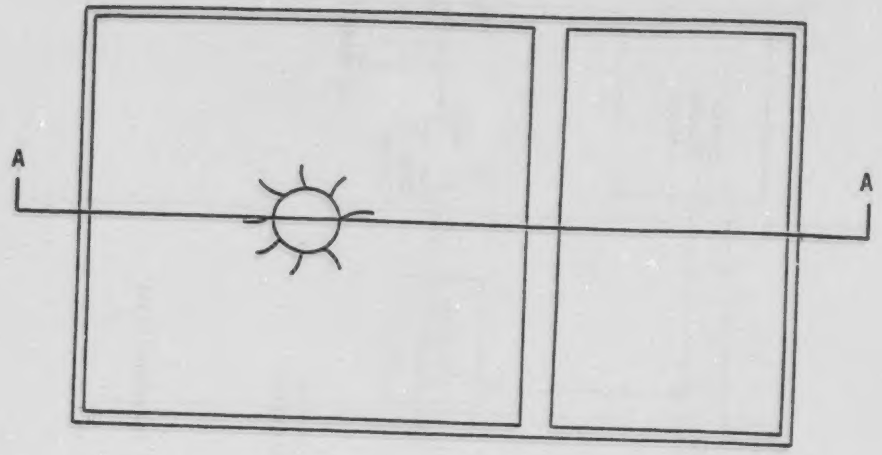
The total annual costs presented include the annual operating cost plus an 11% annual amortization allowance on capital cost (10% interest rate; 25 year amortization period). Unit treatment costs (i.e. cost per m^3 of wastewater treated and cost per kilogram of BOD_5 removed) are based on the total annual cost and quantity of wastewater treated annually.

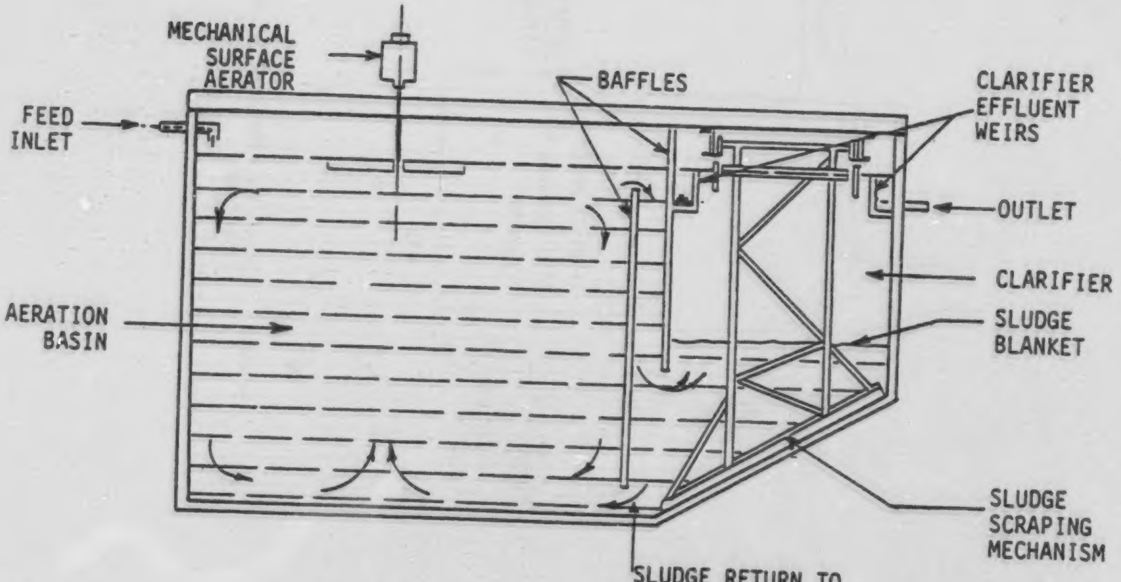
MEAT AND POULTRY PLANTS

Plant A

Plant A is a poultry processing operation that slaughters approximately 18,000 birds/day on an 8 hr/day, 5 day/week basis.

An extended aeration plant with integral clarifier, as shown in Figure 1, was installed in 1972 to treat an average wastewater flow of 455 m^3/day (100,000 Igpd). As illustrated in Figure 2 the waste treatment facilities include screening of the raw wastewater, aeration, clarification and physical/chemical treatment of the clarifier effluent.





SECTION A-A

FIGURE 1 - AERATION BASIN
WITH INTEGRAL CLARIFIER

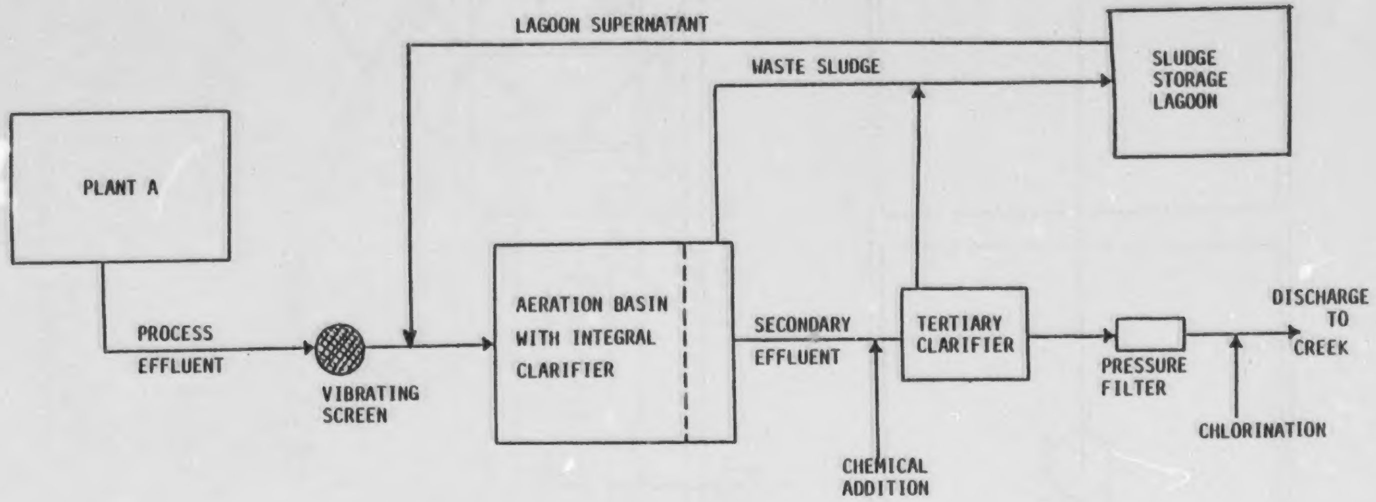


FIGURE 2 - Schematic Flow Sheet of Waste Treatment Plant (Plant A)

The operating and design criteria for the extended aeration plant are summarized in Table 1.

Current wastewater flow rates average approximately 318 m^3/day (70,000 Igpd) and the process is generally achieving BOD_5 and suspended solids removals of greater than 95% and 90% respectively. Clarifier effluent BOD_5 concentrations are less than 30 mg/L and suspended solids concentrations are less than 40 mg/L.

The wasting of biological sludge is practiced very infrequently. When carried out, sludge is discharged to an abandoned 3 stage lagoon system on the plant property. Supernatant from the lagoon is returned to the aeration basin during periods of low flow.

Shortly after start-up, a problem of turbulence in the integral secondary clarifier was encountered. This was apparently solved by adding anti-rotational baffles to three sides of the aeration basin.

Freezing problems were also encountered with the integral clarifier, although these were alleviated by enclosing the clarifier in a metal structure, and blowing warm air over the liquid surface.

The waste treatment facility is operated and maintained on a part-shift basis by one man, who is also responsible for maintenance of the plant's boiler room.

Construction of the plant was completed in April 1972 at a cost of approximately $257,000 (including tertiary physical/chemical treatment). Using the ENR construction cost index for updating purposes, this corresponds to a November 1977 cost of approximately $400,000 as shown in Table 2.

Annual operating and maintenance costs for the extended aeration phase of the treatment process are estimated at approximately $18,600.

Plant B

Plant B is a poultry operation that slaughters and processes approximately 38,000 birds/8 hour-day, 5 days per week. All blood, feathers, offal, and dead-on-arrival and contaminated birds are recovered and sent to an on-site rendering facility.

Grease is recovered from the process wastewater for rendering by means of air flotation prior to discharge to a wet-well. The wastewater from the wet-well is then pumped to 4 vibrating screens. The screened waste flows through a splitter box to an extended aeration plant, which is in turn followed by a facultative lagoon, as shown in Figure 3.

The extended aeration plant consists of two earthen aeration basins operated in parallel. These cells are interconnected to permit series operation, if so desired. Overflow from the aeration cells enters a secondary clarifier and sludge removed from the clarifier bottom is recycled to the splitter box.

TABLE 1 - OPERATING AND DESIGN CRITERIA FOR EXTENDED AERATION PROCESS (PLANT A)

Wastewater Characteristics:		
Flow:	Average:	318 m^3/day (70,000 Igpd) - 5 days/week
	Design:	455 m^3/day (100,000 Igpd) - 5 days/week
BOD_5:	Range:	400 - 900 mg/L
	Average:	600 mg/L
SS:	Range:	250 - 500 mg/L
	Average:	400 mg/L
Organic Loading Rate:		0.05 kg BOD_5/kg MLSS/day
Volumetric Loading Rate:		240 g BOD_5/day/m^3 (15 lb BOD_5/1,000 ft^3/day)
MLSS Concentration:		4,000 - 5,000 mg/L
Detention Time:		3 days
Aeration Requirements:		19 kW - Mechanical Surface Aerator (14 kW/1000 m^3 of basin volume)
Secondary Clarifier Overflow Rate:		19.5 m^3/day/m^2 (400 Igpd/ft^2)

TABLE 2 - CAPITAL AND OPERATING COSTS FOR THE EXTENDED AERATION PROCESS (PLANT A)

Capital Cost (adjusted to 1977)	$400,000	
Annual Amortized Capital Cost @ 11%		$44,000
Operating Costs:		
Manpower: 1040 hr/yr @ $10/hr	$10,400	
Electrical Power: 327,000 kW-hr/yr x $0.025/kW-hr	$ 8,200	
Annual Operating Cost		$18,600
Total Annual Cost		$62,600
Cost per m^3 Treated		$0.75 ($3.40/1000 I.G.)
Cost per kg BOD_5 Removed		$1.32 ($0.60/lb)

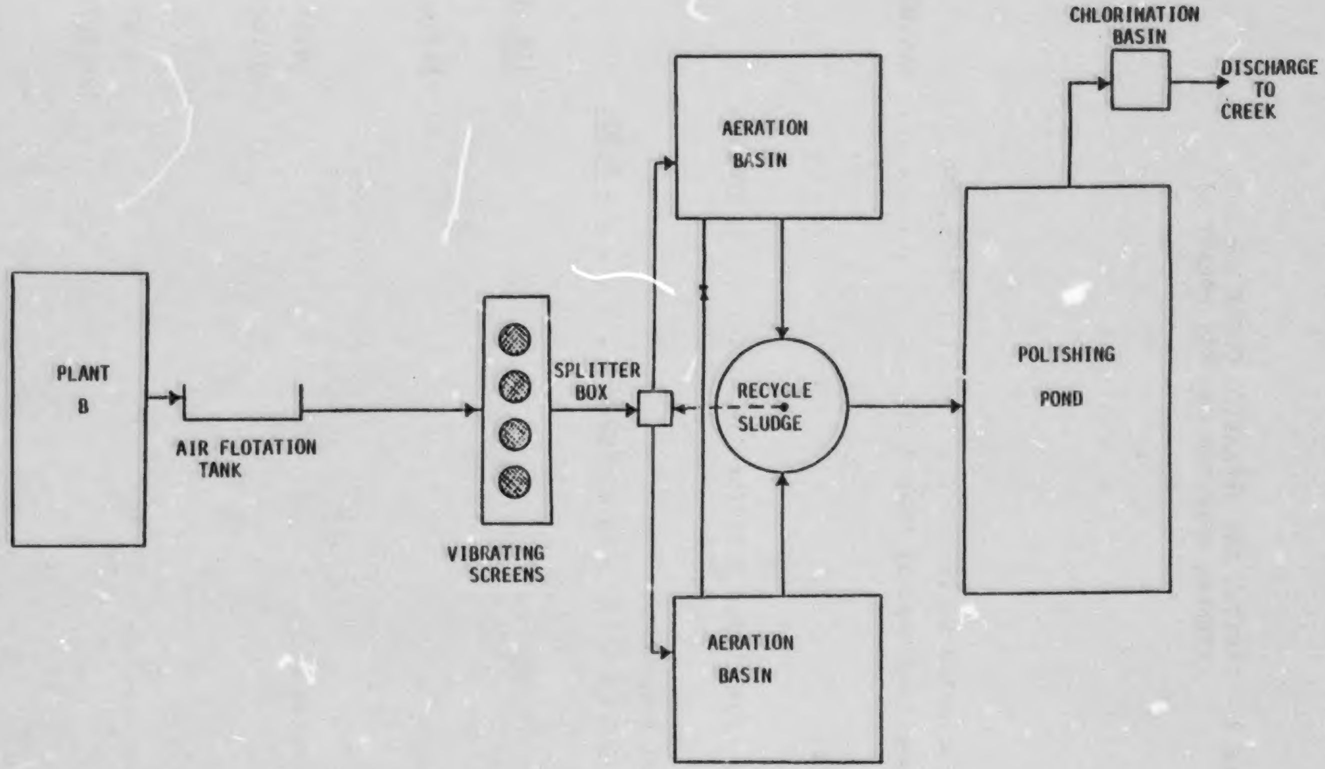


FIGURE 3 - Schematic Flow Sheet of Waste Treatment Process (Plant B)

Clarifier effluent flows to a 1.6 hectare (4 acre) polishing pond and effluent from the pond is chlorinated prior to discharge to a small receiving stream.

The operating and design criteria for the extended aeration plant and lagoon are summarized in Table 3.

Current wastewater flow rates average approximately 1900 m^3/day (425,000 Igpd). Effluent from the secondary clarifier contains less than 30 mg/L BOD_5 and 75 mg/L suspended solids, although this is further reduced to approximately 10 mg/L BOD_5 and 15 mg/L suspended solids in the polishing pond. Overall BOD_5 and suspended solids removals are 98% and 97%, respectively.

Some problems have been encountered with the loss of biological solids from the secondary clarifier. This has been attributed to sludge bulking, and to flow surges which result in increased overflow rates in the clarifier. Chlorination of return sludge to control filamentous organism growth and reduce bulking has been conducted on an experimental basis but results were inconclusive. It is believed that flow equalization would help alleviate the problem, but equipment and facilities are not available to test this.

The presence of high concentrations of algae in the polishing lagoon in summer months imparts a green colour to the final effluent. For this reason, the polishing pond has been by-passed for short periods during the summer to prevent the discharge of aesthetically unacceptable effluent.

Winter operation has resulted in some icing problems, particularly with the rotating skimmer arm of the secondary clarifier. This has necessitated removal of the arm in fall to facilitate winter operation. In addition, it has been found necessary to chip ice from the umbrella which forms around the two surface aerators.

Sludge wasting has not been necessary for the past two years, however when carried out, the sludge is trucked to a landfill site.

The waste treatment plant is operated by one man on a full-time basis.

Capital and operating costs for the treatment plant are presented in Table 4. The plant was constructed in 1972 at a cost of approximately $500,000 (excluding land), which corresponds to a November 1977 cost of approximately $780,000, based on the ENR construction cost index. Annual operating and maintenance costs are estimated at $50,800.

Plant C

Plant C is a hog processing and rendering operation, slaughtering approximately 4,000 hogs/day on an eight hour/day, five day/week basis.

TABLE 3 - OPERATING AND DESIGN CRITERIA FOR EXTENDED AERATION/POLISHING LAGOON PROCESS (PLANT B)

Wastewater Characteristics:		
Flow -	Average:	1900 m^3/day (425,000 Igpd) - 5 days/week (Average Flow during 8 hour processing period is approximately 38 L/sec) (Overnight and Weekend Flow is approximately 11 L/sec)
BOD_5:	Range:	300 - 2,000 mg/L
	Average:	800 mg/L
SS:	Range:	300 - 1,000 mg/L
	Average:	500 mg/L
Extended Aeration System:		
Organic Loading Rate:		0.02 - 0.05 kg BOD_5/kg MLSS/day
Volumetric Loading Rate:		160 - 320 g BOD_5/day/m^3 (10 - 20 lb BOD_5/1,000 ft^3/day)
MLSS Concentration:		3800 - 5200 mg/L
Detention Time:		5.5 days
Aeration Requirements:		2 Mechanical Surface Aerators - 1 @ 56 kW and 1 @ 75 kW (12 kW/1000 m^3 of basin volume)
Secondary Clarifier:		Overflow Rate - 19.5 m^3/day/m^2 (400 Igpd/ft^2) at 26 L/s (350 Igpm)
Polishing Lagoon:		
Organic Loading Rate:		2.2 g/day/m^2 (20 lb BOD_5/acre/day)
Depth:		1.8 m (6 ft)

TABLE 4 - CAPITAL AND OPERATING COSTS OF EXTENDED AERATION/POLISHING LAGOON PROCESS (PLANT B)

Capital Cost (adjusted to 1977)	$780,000	
Annual Amortized Capital Cost @ 11%		$85,000
Operating Costs:		
Manpower: 2080 hr/yr @ $10/hr	$20,800	
Electrical Power: 118,000 kW-hr/yr x $0.025/kW-hr	$30,000	
Annual Operating Cost		$50,800
Total Annual Cost		$135,000
Cost per m^3 Treated		$0.26 ($1.20/1000 I.G.)
Cost per kg BOD_5 Removed		$0.33 ($0.15/lb)

The wastewater treatment facility is comprised of an extended aeration process preceded by anaerobic lagoons. The raw waste is screened, and passed through an air flotation unit for removal of solids, fats, and grease. It then flows to a splitter box, where it can be diverted to either or both of two anaerobic lagoons operated in parallel (only one anaerobic lagoon is in use at present). Effluent from the lagoons enters a common aeration basin from which it is discharged to a secondary clarifier. Clarifier overflow is then chlorinated and either discharged directly to a nearby river, or stored in a holding pond if the effluent quality is unacceptable. Sludge from the secondary clarifier is returned to the aeration tank to maintain an MLSS concentration of approximately 5,000 mg/L. Excess sludge is wasted to the anaerobic lagoons for digestion, thereby eliminating any sludge handling problems.

A schematic flow diagram of the treatment process is illustrated in Figure 4. Operating and design criteria for the treatment plant are summarized in Table 5.

Winter wastewater temperatures have necessitated construction of a prefabricated building over the final clarifier to reduce icing problems. Mechanical failure of the aerator vanes, due to ice build-up, has also been encountered.

The use of the holding pond for effluent polishing in cold weather has been found beneficial in maintaining a high quality effluent on a year-round basis.

The plant is maintained by a trained operator on a full-time (8 hr/day, 5 day/week) basis. The operator monitors influent and effluent quality, sludge settleability, MLSS concentration and dissolved oxygen on a daily or weekly basis, depending upon the stability of the process performance. Close monitoring of the process has revealed that significant power savings can be realized, without impairing treatment performance, by operating two aerators continuously and two only 50% of the time.

Since its construction in 1975, the plant has been producing a final effluent with less than 30 mg/L BOD_5 and suspended solids. The anaerobic lagoon has achieved approximately 60% removal of BOD_5 and 50% of suspended solids. Overall treatment efficiency is approximately 98% for BOD_5 removal and 96% for suspended solids.

No data is available on the construction cost of the plant, but operating costs are estimated at approximately $49,000 annually as shown in Table 6.

Plant D

Plant D is a small slaughtering and meat packing facility. Beef, pork and lamb are processed at an average rate of approximately 9,000 kg (20,000 lbs) LWK/day on an 8 hour/day, 5 day/week basis.

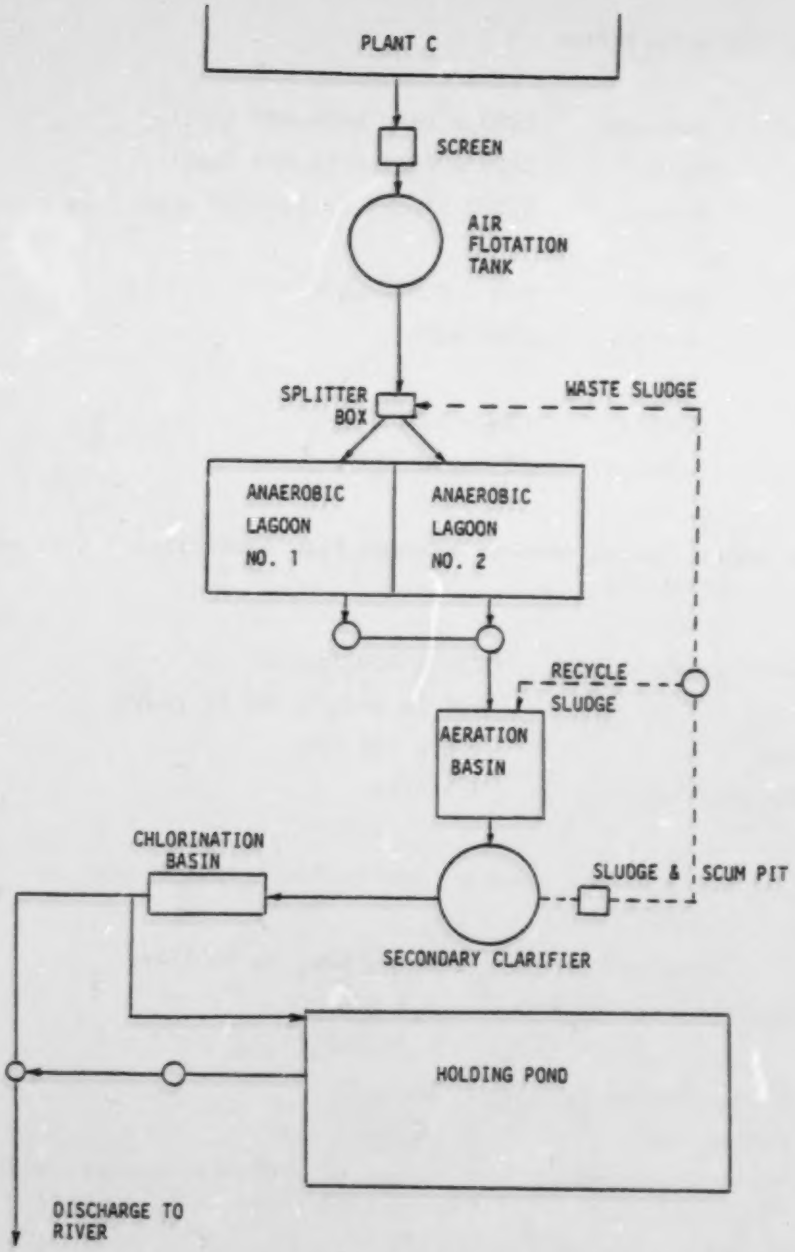


FIGURE 4 - Schematic Flow Sheet of Waste Treatment Process (Plant C)

TABLE 5 - OPERATING AND DESIGN CRITERIA FOR ANAEROBIC LAGOON/EXTENDED AERATION PROCESS (PLANT C)

Wastewater Characteristics:

Flow -	Average:	1820 m^3/day (400,000 Igpd)
	Peak:	3410 m^3/day (750,000 Igpd)
	Design:	5,000 m^3/day (1,100,000 Igpd)
BOD$_5$:	Range:	700 - 2,000 mg/L
	Average:	1500 mg/L
SS:	Range:	400 - 1,200 mg/L
	Average:	800 mg/L

Anaerobic Lagoon (under present average flow conditions - i.e. only one lagoon in operation)

Organic Loading Rate:	270 g BOD$_5$/day/m^3 (17 lb BOD$_5$/1,000 ft^3/day)
Depth:	4.6 m (15 ft)
Detention Time:	7.3 days

Extended Aeration (under present average flow conditions):

Organic Loading Rate:	<0.04 kg BOD$_5$/kg MLSS/day
Volumetric Loading Rate:	<176 g BOD$_5$/day/m^3 (11 lb BOD$_5$/1,000 ft^3/day)
MLSS Concentration:	5,000 mg/L
Detention Time:	2.8 days
Aeration Requirements:	4 Mechanical Surface Aerators @ 37 kW each (20 kW/1000 m^3 of Basin Volume)
Secondary Clarifier Overflow Rate:	9.8 m^3/day/m^2 (200 Igpd/ft^2)

Polishing Pond (under present average flow conditions):

Detention Time:	86 days

TABLE 6 - OPERATING COST OF ANAEROBIC LAGOON/EXTENDED AERATION PROCESS (PLANT C)

Capital Cost	Not Available
Operating Costs:	
Manpower: 2080 hr/yr @ $10/hr	$20,800
Electrical Power: 1.1×10^6 kW-hr/yr x $0.025/kW-hr	$28,000
Annual Operating Cost	$48,800

As shown in Figure 5, plant wastewater is collected in a small sump and pumped to a vibrating screen for separation of gross solids. From here it flows to an oxidation ditch, and finally to a secondary clarifier prior to discharge to a small creek. Sludge from the clarifier bottom may be either returned to the ditch or drawn off for discharge to drying beds.

Operating and design criteria for the oxidation ditch installation are presented in Table 7.

The wastewater flow through the treatment plant is generally between 14 and 29 m^3/day (3,000 and 6,500 Igpd), 5 days per week. With few exceptions, the process has consistently been able to achieve effluent BOD_5 and suspended solids concentrations of less than 40 and 50 mg/L respectively, despite the concentrated and variable nature of the waste. This corresponds to removals of 98% and 90% for BOD_5 and suspended solids, respectively.

The oxidation ditch was constructed in 1963. No data are available on the capital cost of the plant, however, annual operating costs are estimated at less than $3,000, as calculated in Table 8.

The operational requirements of the process have been found to be minimal. Return sludge from the secondary clarifier is wasted, as required, by discharging it directly to sludge drying beds located on the plant property. Sludge settleability, pH, and dissolved oxygen are measured on a regular basis.

Due to low alkalinity of the wastewater, sodium bicarbonate must be added to provide buffering capacity and to stabilize pH in the 6.5 to 7.0 range. Prior to the addition of sodium bicarbonate, the process was operating relatively unsuccessfully at a pH of approximately 4.7.

Plant E

Plant E is a hog processing and rendering operation, slightly larger than Plant C, slaughtering approximately 5,000 hogs per 8 hour day, 5 to 6 days/week.

The wastewater treatment facility is a trickling filter process preceded by anaerobic lagoons. Pretreatment of wastes from the kill floor consists of screening followed by air flotation. Effluent from the flotation unit is combined with other processing and domestic wastewater, and sent to two anaerobic lagoons operated in parallel for biological treatment and flow equalization. Lagoon effluent is then preaerated and pumped to two plastic media trickling filter towers operated in series. Secondary clarification in two parallel clarifiers and disinfection of effluent is then carried out prior to discharge to a nearby river. Sludge from the clarifiers is returned to the anaerobic lagoons for digestion. A schematic flow diagram of the process is illustrated in Figure 6.

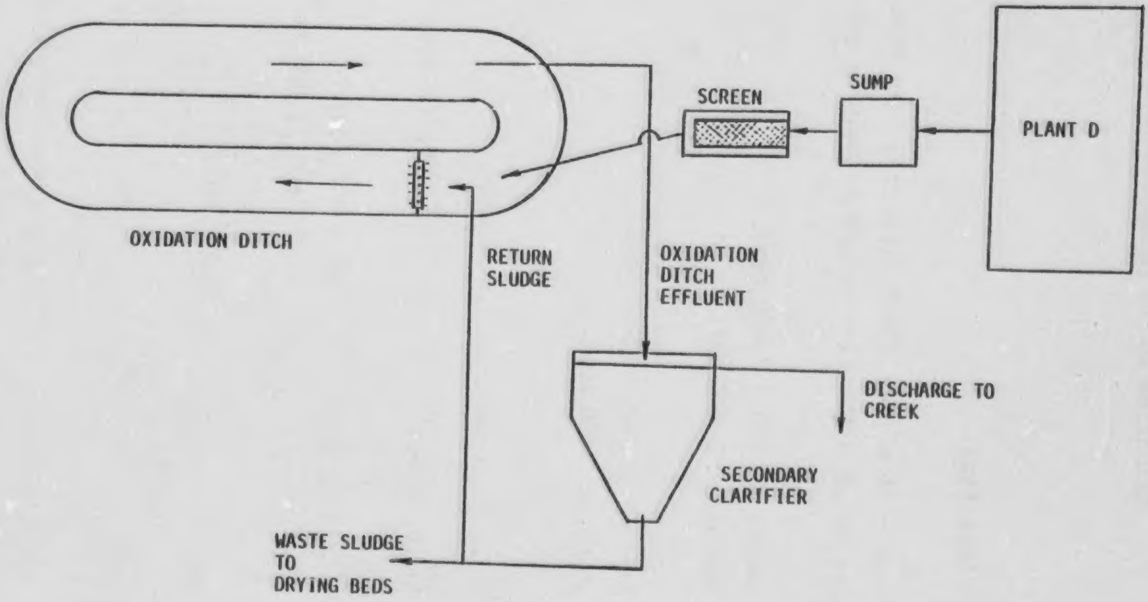


FIGURE 5 - Schematic Flow Sheet of Waste Treatment Process
(Plant D)

TABLE 7 - DESIGN AND OPERATING CRITERIA FOR OXIDATION DITCH PROCESS (PLANT D)

Wastewater Characteristics:

Flow: Average - 26 m^3/day (5700 Igpd) - 5 days/week
(Majority of Daily Flow Occurs in 8-10 hr period)

BOD_5: Range: 500 - 7,000 mg/L
Average: 2,200 mg/L

SS: Range: 400 - 1,400 mg/L
Average: 600 mg/L

Oxidation Ditch:

Organic Loading Rate: 0.12 kg BOD_5/kg MLSS/day

Volumetric Loading Rate: 368 g BOD_5/day/m^3
(23 lb BOD_5/1,000 ft^3/day)

MLSS Concentration: 3,000 mg/L

Detention Time: 5.8 days

Aeration Requirements: 3.7 kW Cage Rotor
(25 kW/1000 m^3 of basin volume)

TABLE 8 - OPERATING COSTS FOR OXIDATION DITCH PROCESS (PLANT D)

Capital Cost	Not Available
Operating Cost:	
Manpower: 260 hr/yr @ $10/hr	$2,600
Electrical Power: 7,500 kW-hr/yr x $0.025/kW-hr	$ 190
Annual Operating Cost	$2,790

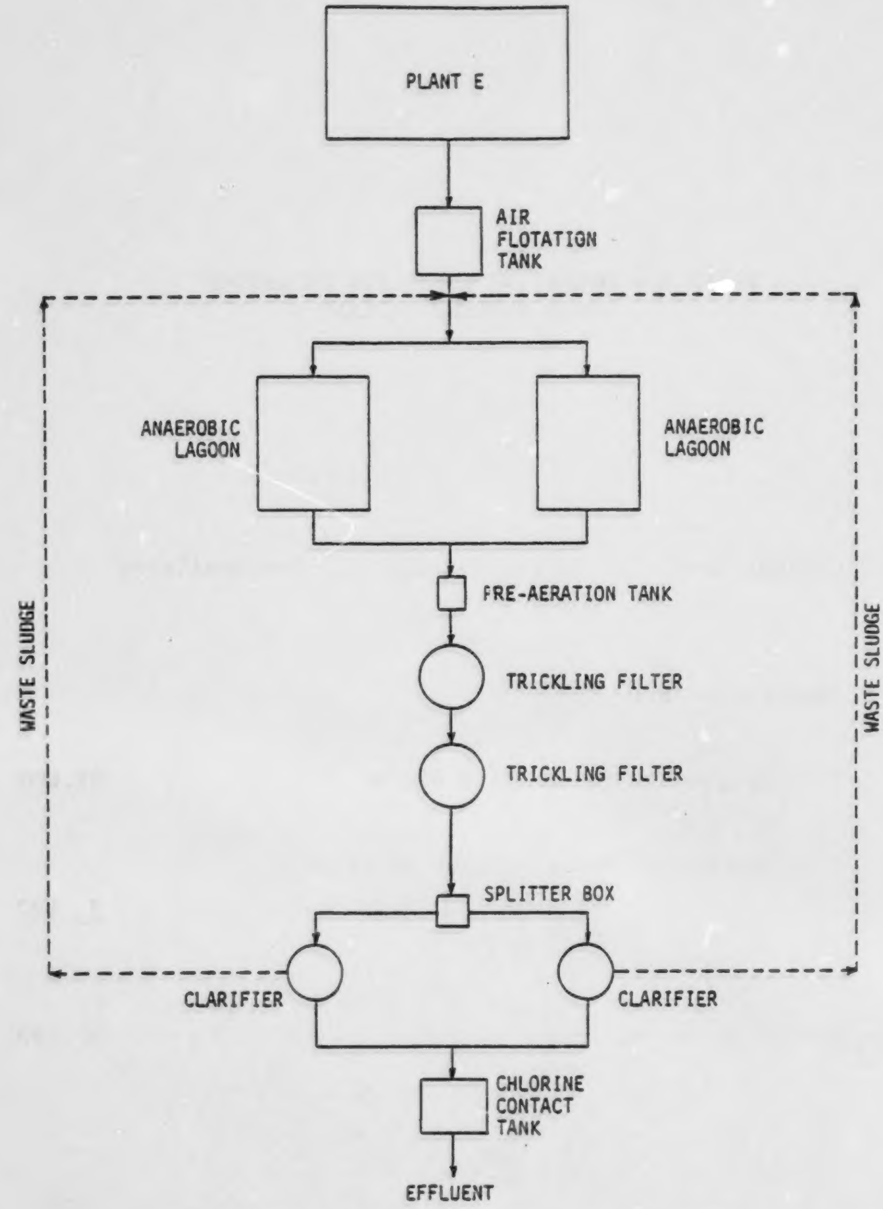


FIGURE 6 - SCHEMATIC FLOW SHEET OF WASTE TREATMENT PROCESS (PLANT E)

Operating and design criteria for the treatment plant are summarized in Table 9.

Some problems have been encountered with reduced treatment efficiency and filter freezing during cold weather operation. The filters, originally open to the air, have been enclosed to help retain heat and alleviate this problem. Some clogging of the distributor arms and filter media has also been experienced; otherwise the trickling filters have operated with very few problems.

A distinct odour of hydrogen sulphide was evident in the vicinity of the anaerobic lagoons, but this has reportedly not caused any complaints from a nearby residential area. Sludge removal from the anaerobic cells has only been required once to date.

The plant is maintained by a trained operator on a full-time basis and consistently produces a final effluent with less than 70 mg/L BOD_5 and 80 mg/L of suspended solids (greater than 97% removal of both parameters). The anaerobic lagoons are providing approximately 60% BOD_5 removal and 65% removal of suspended solids.

The treatment plant construction was completed in 1969 at a cost of $500,000. As shown in Table 10, the estimated total capital cost of such a project in 1977 dollars is approximately $1,100,000. The annual operating and maintenance cost of the facility is estimated at approximately $40,000.

DAIRIES AND MILK PRODUCTS PLANTS

Plant F

Plant F is a dairy operation with a peak milk production of approximately 195,000 kg (430,000 lbs) of raw milk per day. The principal products are butter, dried milk, and skim milk powder. Plant production is highly seasonal. During the peak production season (summer), the plant operates 24 hours per day, 7 days/week. This drops off to a 16 hour/day, 5 day/week production schedule as the availability of raw milk decreases. The plant has been forced to shut down during the winter season in recent years due to insufficient supplies of raw milk to warrant operation.

An oxidation ditch process, as shown in Figure 7, is used to treat an average wastewater flow of 160 m^3/day (35,000 Igpd). Wastewater is collected in a wet-well and pumped to a 25 m^3 (5,500 gallon) equalization tank. The waste flows from the bottom of the tank, at a rate proportional to static head of liquid in the tank, into an open channel to the oxidation ditch. Overflow from the ditch enters a secondary clarifier housed in a small building which also contains the sludge return pumps. Clarified effluent is discharged to a nearby river.

Design and operating criteria are summarized in Table 11.

TABLE 9 - OPERATING AND DESIGN CRITERIA FOR ANAEROBIC LAGOON/TRICKLING FILTER PROCESS (PLANT E)

Wastewater Characteristics:

Flow:	Range:	1820 - 3180 m^3/day (400,000 - 700,000 Igpd)
	Average:	2730 m^3/day (600,000 Igpd)
BOD_5:	Range:	2,000 - 5,000 mg/L
	Average:	3,000 mg/L
SS:	Range:	2,000 - 4,000 mg/L
	Average:	3,000 mg/L

Anaerobic Lagoons:

Organic Loading:	320 g BOD_5/day/m^3 (20 lb BOD_5/1,000 ft^3/day)
Depth:	4.3 m (14 ft)
Detention Time:	9.7 days

Trickling Filters:

	Filter No. 1	Filter No. 2
Organic Loading		
kg BOD_5/day/m^3)	864	384
(lb BOD_5/1,000 ft^3/day)	54	24
Hydraulic Loading		
(m^3/day/m^2)	24	24
(Igpd/ft^2)	500	500
Depth (m)	6.7	6.7
Media	PVC	PVC

Secondary Clarifiers:

Overflow Rate:	28 m^3/day/m^2 (565 Igpd/ft^2)

TABLE 10 - PROCESS PERFORMANCE AND COST OF ANAEROBIC LAGOON/EXTENDED AERATION PROCESS (Plant E)

Capital Cost (adjusted to 1977)	$1,100,000	
Annual Amortized Capital Cost @ 11%		$121,000
Operating Cost:		
Manpower: 2080 hr/yr @ $10/hr	$20,800	
Electrical Power: 149,000 kW-hr/yr x $0.025/kW-hr	$ 3,700	
Maintenance Allowance	$15,000	
Annual Operating Cost		$ 39,500
Total Annual Cost		$160,500
Cost per m^3 Treated		$0.23 ($1.03/1000 I.G.)
Cost per kg BOD_5 Removed		$0.077 ($0.035/lb)

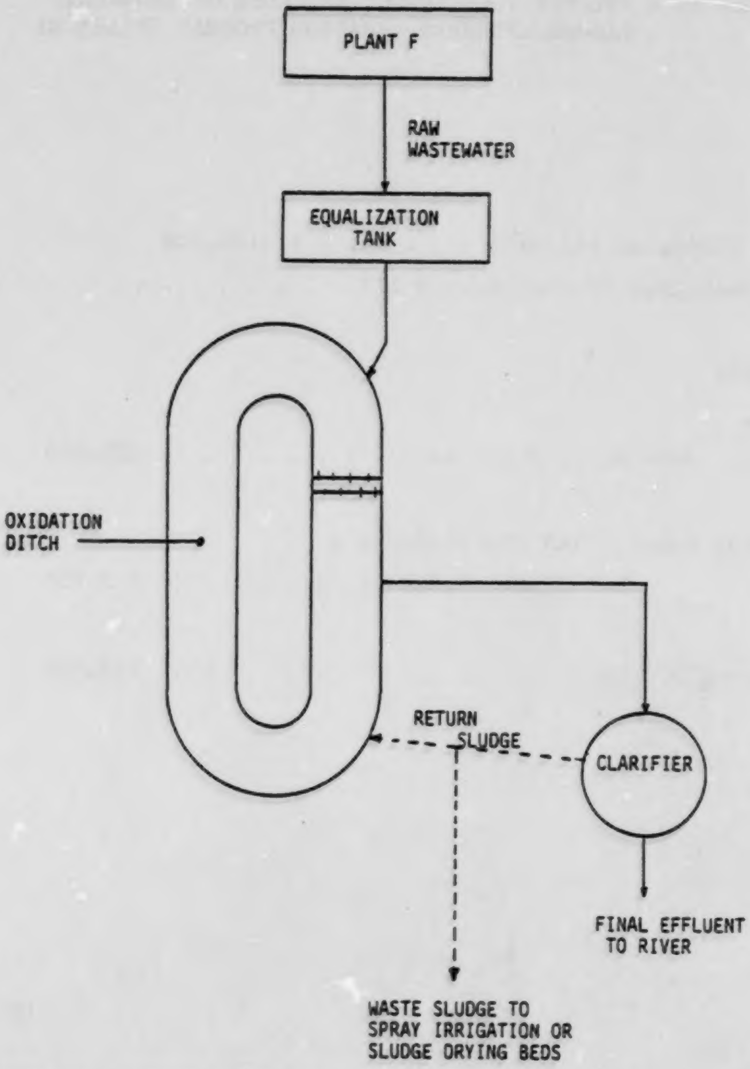


FIGURE 7 - SCHEMATIC FLOW SHEET OF WASTE TREATMENT PROCESS (PLANT F)

TABLE 11 - OPERATING AND DESIGN CRITERIA FOR OXIDATION DITCH PROCESS (PLANT F)

Wastewater Characteristics:

Flow:	Summer:	160 - 180 m^3/day (35,000 - 40,000 Igpd)
	Winter:	45 - 55 m^3/day (10,000 - 12,000 Igpd)
Design Flow:		160 m^3/day (35,000 Igpd)
BOD_5:	Range:	500 - 1900 mg/L
	Average:	950 mg/L
SS:	Range:	600 - 2500 mg/L
	Average:	1240 mg/L

Oxidation Ditch:

Depth:	1.5 m (5 ft)
Detention Time:	3.1 days
MLSS Concentration:	4,000 mg/L
Organic Loading:	0.076 kg BOD_5/kg MLSS/day
Volumetric Loading:	300 g BOD_5/day/m^3 (19 lb BOD_5/1000 ft^3/day)
Aeration Requirements:	19 kW Cage Rotor (21 kW/1000 m^3)

Clarifier:

Diameter:	4.3 m (14 ft)
Overflow Rate:	11 m^3/day/m^2 (230 Igpd/ft^2)

Sludge is wasted from the process on a daily basis in summer months by means of spray irrigation on 7.3 hectares (18 acres) of plant property. Sludge wasting occurs only intermittently in winter to sludge drying beds.

The major problem encountered in operation of the plant has been the loss of solids from the secondary clarifier due to flow surges. While the equalization tank provides some balancing of flow, this is insufficient to prevent the rising of the sludge blanket in the clarifier and subsequent loss of solids during extended periods of high flow.

The clarifier design is such that settled sludge has a tendency to cling to the conical sides and bottom. This necessitates daily scraping to remove the sludge and prevent problems of septicity and denitrification from occurring.

Some problems with ice formation on the aeration rotor have also been encountered in winter operation.

The oxidation ditch process has performed very effectively with 99% BOD_5 removal and 98% removal of suspended solids. Average effluent concentrations of BOD_5 and suspended solids are 7 mg/L and 28 mg/L, respectively.

The plant operator spends approximately one hour per day maintaining the plant. This involves a daily sludge settleability test, scraping of the clarifier bottom and a weekly BOD_5 analysis.

The waste treatment plant was constructed in 1972 at a cost of approximately $70,000. As shown in Table 12, the updated value of the plant is estimated at $110,000, and annual operating costs at $6,600.

Plant G

Plant G is a condensed milk operation that processes an average of approximately 159,000 kg (350,000 lbs) of raw milk per day. Plant production is highly seasonal, depending upon availability of raw milk, although production is generally carried out 8 hours/day, 6 days/week.

As shown in Figure 8, the waste treatment process employed by Plant G, consists of a combined extended aeration, trickling filter process. The average daily flow of 160 m^3/day (35,000 Igpd) is passed through a grease trap and screen prior to reaching a preaeration basin. Wastewater from the preaeration cell is pumped at a constant rate of 38 L/s (500 Igpm) to a trickling filter with rock media. Underflow from the trickling filter is returned to the preaeration basin and overflow from this cell enters a second aerated cell, which carries a much higher concentration of mixed liquor suspended solids. Effluent from this stage in turn passes to a third aeration basin and finally to a rectangular clarifier prior to discharge to a municipal sewer.

TABLE 12 - CAPITAL AND OPERATING COSTS FOR OXIDATION DITCH PROCESS (PLANT F)

Capital Cost (adjusted to 1977)	$110,000	
Annual Amortized Cost @ 11%		$12,100
Operating Costs:		
Manpower: 260 hrs/yr x $10/hr	$ 2,600	
Electrical Power: 160,000 kW-hrs/yr x $0.025/kW-hr	$ 4,000	
Annual Operating Cost		$ 6,600
Total Annual Cost		$18,700
Cost per m^3 Treated		$0.32 ($1.46/1000 I.G.)
Cost per kg BOD_5 Removed		$0.35 ($0.16/lb)

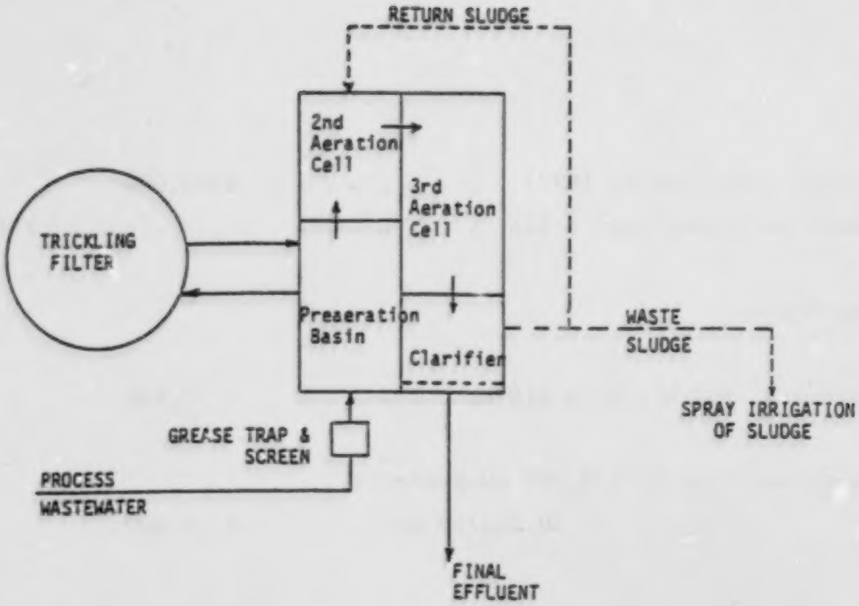


FIGURE 8 - SCHEMATIC FLOW SHEET OF WASTE TREATMENT PROCESS (PLANT G)

Operating and design criteria for the plant are summarized in Table 13. Sludge removed from the clarifier bottom is returned to the second aeration basin. In summer months, approximately 6.8 m^3 (1,500 I.G.) of return sludge are wasted per week by spraying on plant property.

Problems which have been encountered with the trickling filter include ice buildup in winter months and some filter fly nuisance in summer. Many problems have occurred with clogging of the carborundum type air diffusers in the aeration basins. This has necessitated daily brushing and frequent removal of the diffusers to prevent excessive pressure buildup in the aeration piping.

Discharges of high concentrations of suspended solids has been another problem with the process. Since the majority of the total daily flow occurs in the last 3 hours of an 8 hour shift, during wash-up operations, a flow surge occurs. This results in increased overflow rates in the secondary clarifier and the resultant loss of solids.

Approximately one hour per day is spent in maintaining the plant. When operating well, an effluent BOD concentration of less than 25 mg/L and less than 100 mg/L of suspended solids is generally achieved.

An estimate of the capital cost of the waste treatment facility was not available, but annual operating costs are estimated at approximately $6,000 as shown in Table 14.

Plant H

Plant H is a 24 hour/day, 7 day/week milk processing operation. The main products are cheese and butter, with dried whey being sold as a by-product.

The waste treatment facility consists of a 7-stage RBC unit followed by aerated lagoons. As shown in Figure 9, aqueous ammonia is added to the flow equalization/preaeration basin ahead of the RBC unit, due to a nitrogen deficiency in the waste. Intermediate clarification follows the first three stages of RBC treatment. Effluent from the intermediate clarifier is then further treated in an additional four RBC stages, and discharged to a secondary clarifier. Secondary clarifier effluent is subsequently passed through a 2-cell aerated lagoon system, and a settling basin prior to discharge. The wastewater flow of 590 m^3/day (130,000 Igpd) is relatively consistent year-round.

Operating and design criteria for the waste treatment process are summarized in Table 15.

The plant is maintained by one operator on a full time (8 hour/day, 5 day/week) basis, who monitors the process daily.

TABLE 13 - OPERATING AND DESIGN CRITERIA FOR EXTENDED AERATION/TRICKLING FILTER PROCESS (PLANT G)

Wastewater Characteristics:

Flow:	Range:	114 - 295 m^3/day (25,000 - 65,000 Igpd)
	Average:	160 m^3/day (35,000 Igpd)
BOD_5:	Range:	300 - 2,200 mg/L
	Average:	1,000 mg/L
SS:	Range:	150 - 500 mg/L
	Average:	300 mg/L

Trickling Filter:

Depth: 1.4 m (4.5 ft)
Diameter: 21.4 m (70 ft)
Organic Loading Rate: 320 g BOD_5/day/m^3 (20 lb BOD_5/1000 ft^3/day)
Hydraulic Loading Rate: 0.44 m^3/day/m^2 (9 Igpd/ft^2)
Media: Rock

Extended Aeration Process:

1st Cell: Detention Time - 18 hours
2nd Cell: Detention Time - 15 hours
3rd Cell: Detention Time - 24 hours

Overall Aeration Requirements:

Diffused Aeration
(41 kW/1000 m^3 of basin volume)

Secondary Clarifier:

Overflow Rate - 6.8 m^3/day/m^2 (140 Igpd/ft^2)

TABLE 14 - OPERATING COSTS FOR THE EXTENDED AERATION/TRICKLING FILTER PROCESS (PLANT G)

Costs:	
Capital Cost	Not Available
Operating Costs:	
Manpower: 260 hrs/yr x $10/hr	$2,600
Electrical Power: 131,400 kW-hrs/yr x $0.025/kW-hr	$3,300
Annual Operating Cost	$5,900

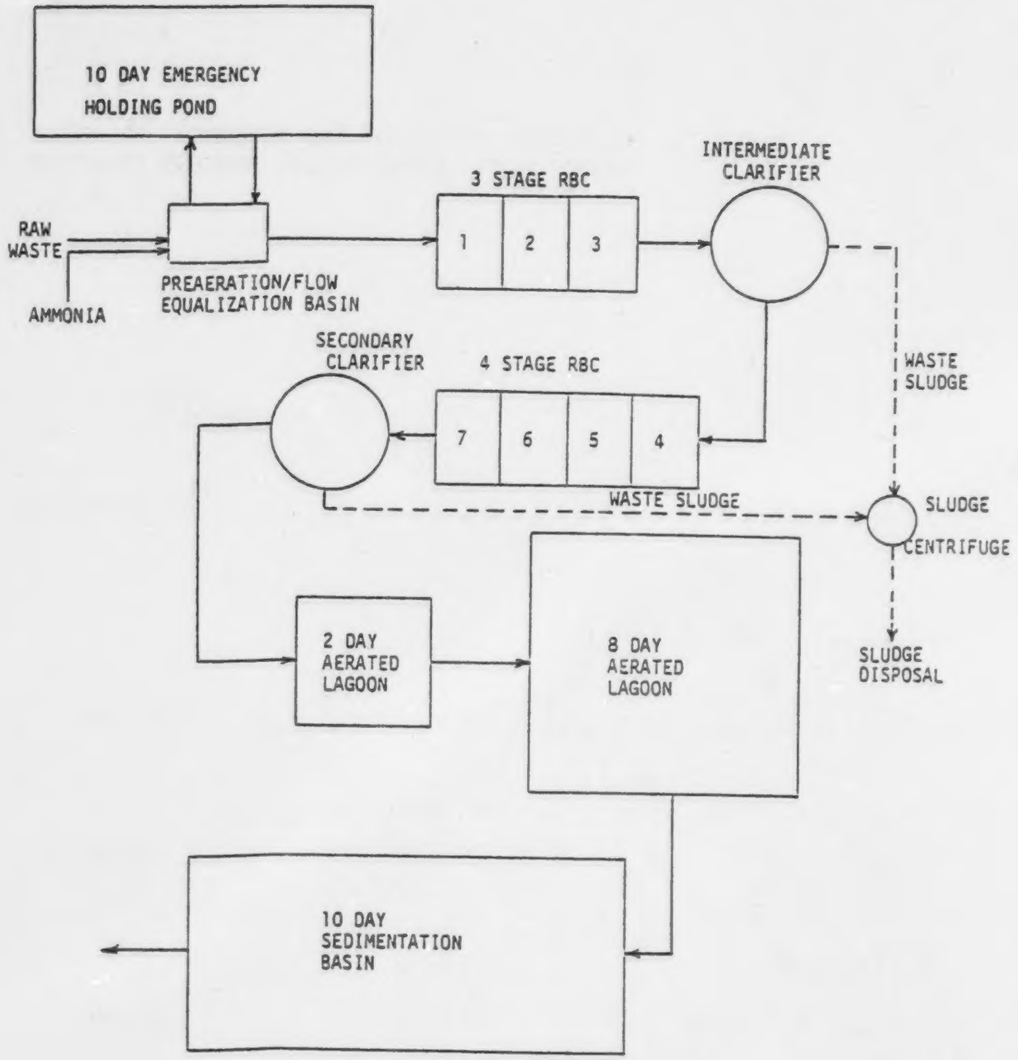


FIGURE 9 - SCHEMATIC FLOW SHEET OF WASTE TREATMENT PROCESS (PLANT H)

TABLE 15 - OPERATING AND DESIGN CRITERIA FOR RBC/ AERATED LAGOON PROCESS (PLANT H)

Wastewater Characteristics:
- Flow: 590 m^3/day (130,000 Igpd) - little variance
- BOD_5: 3,400 mg/L
- SS: 3,200 mg/L

Preaeration/Flow Equalization Basin:
- Volume: 455 m^3 (100,000 I.G.)
- Detention Time: 18 hours

First 3 RBC Stages:
- Surface Area per stage: 16,700 m^2 (180,000 ft^2)
- Organic Loading Rate: 40 g/day/m^2 (8.2 lb BOD_5/1000 ft^2/day)
- Hydraulic Loading Rate: 0.012 m^3/day/m^2 (0.24 Igpd/ft^2)

Intermediate Clarifier:
- Overflow Rate: 36 m^3/day/m^2 (735 Igpd/ft^2)

Last 4 RBC Stages:
- Surface Area per stage: 16,700 m^2 (180,000 ft^2)
- Hydraulic Loading Rate: 0.0088 m^3/day/m^2 (0.18 Igpd/ft^2)

Secondary Clarifier:
- Overflow Rate: 36 m^3/day/m^2 (735 Igpd/ft^2)

Aerated Lagoons:
- First Cell: Detention Time - 2 days
  Organic Loading - 320 g/day/m^3 (20 lb BOD_5/1000 ft^3/day)
- Second Cell: Detention Time - 8 days

Aeration Requirements
- Diffused Air with 3 blowers @ 75 kW each to aerate preaeration basin plus both aerated lagoon cells
- Only one blower in use at present
- Average overall aeration requirements = 12 kW/1000 m^3 (72 hp/MIG)

Final Settling Basin: Detention Time - 10 days

The RBC/aerated lagoon process has performed exceptionally well and demonstrated an ability to attain very high treatment efficiencies. The RBC system with secondary clarifier is achieving approximately 90% removal of BOD_5 and 86% suspended solids removal. Final effluent from the aerated lagoon system contains less than 25 mg/L of BOD_5 and suspended solids, for overall removals in excess of 99% for both parameters.

The major difficulty that has been encountered with the operation of this plant has been the handling of voluminous amounts of waste sludge produced by the RBC process. Sludge collected from the intermediate and secondary clarifiers is dewatered in a centrifuge and hauled away for spreading on 65 hectares (160 acres) of pasture land. Approximately 9 m^3/day (2,000 Igpd) of dewatered sludge must be disposed of in this fashion.

As shown in Table 16, the estimated present value of the plant is approximately $815,000. It was constructed in 1975 at a cost of $700,000. Operating costs are estimated at approximately $47,000 annually.

FRUIT AND VEGETABLE PROCESSING PLANTS

Plant I

Plant I is a potato processing plant operating 24 hours/day, 5 to 6 days per week. It processes an average 0.68 million kilograms (1.5 million pounds) of potatoes per day.

The average wastewater flow of 2800 m^3/day (625,000 Igpd) is treated by a high rate trickling filter (biofilter) process as illustrated in Figure 10. In-plant pretreatment processes consist of a mud pit for removal of field stones, dirt and sprouts from the fluming water, a grease trap for removal of free floating grease from the french fry operation, and scalping and vibrating screens for gross solids removal from the combined wastewater stream.

Screened wastewater is passed through a primary clarifier and then to two high rate plastic media trickling filters operated in series with interstage settling. Effluent from the second trickling filter flows to a secondary clarifier prior to discharge to a river. A fraction of the final effluent is also recirculated to the first trickling filter.

Operating and design criteria for the plant are summarized in Table 17.

Sludge removed from the primary clarifier is dewatered on a vacuum filter prior to being hauled some 18 km (11 miles) to a lagoon for final disposal. Secondary sludge is pumped directly to a dewatering and digestion lagoon located on the premises. Supernatant from this lagoon is returned to the trickling filters, with the dried sludge being removed by means of a front end loader and disposed of on land.

TABLE 16 - CAPITAL AND OPERATING COST DATA FOR THE RBC/AERATED LAGOON PROCESS (PLANT H)

Capital Cost (adjusted to 1977)	$815,000	
Annual Amortized Capital Cost @ 11%		$89,700
Operating Costs:		
Manpower: 2080 hrs/yr x $10/hr	$21,000	
Electrical Power:		
980,000 kW-hr/yr x $0.025/kW-hr	$24,500	
Chemicals:	$ 1,400	
Annual Operating Cost		$46,900
Total Annual Cost		$136,600
Cost per m^3 Treated		$0.63 ($2.87/1000 I.G.)
Cost per kg BOD_5 Removed		$0.19 $0.085/lb)

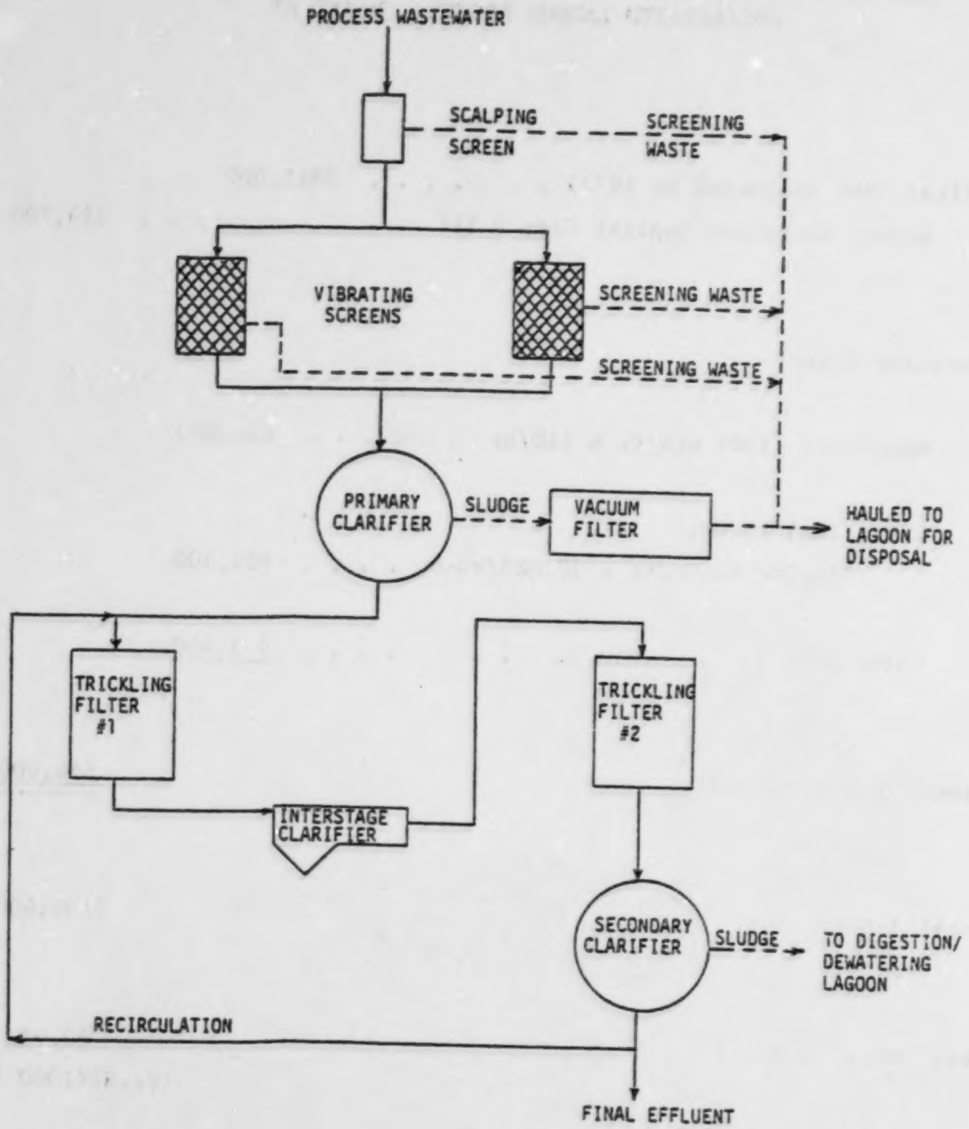


FIGURE 10 - SCHEMATIC FLOW SHEET OF WASTE TREATMENT PROCESS (PLANT I)

TABLE 17 - OPERATING AND DESIGN CRITERIA FOR HIGH RATE TRICKLING FILTER PROCESS (PLANT I)

Wastewater Characteristics:

Flow: Range: 2640 - 3050 m^3/day (580,000 - 670,000 Igpd)
Average: 2800 m^3/day (625,000 Igpd)

BOD_5: Range: 1700 - 4800 mg/L
Average: 2,500 mg/L

SS: Range: 900 - 4200 mg/L
Average: 2,000 mg/L

Primary Clarifier:

Diameter: 20 m (65 ft)
Overflow Rate: 9.8 m^3/day/m^2 (200 Igpd/ft^2)

Trickling Filters:

Dimensions: 12 m x 12 m x 6 m deep (40 ft x 40 ft x 20 ft deep) (each)
Media: Plastic Flocor
Hydraulic Loading: 0.038 m^3/day/m^2 (0.78 Igpd/ft^2) (including recirculation)
Organic Loading: 10,000 g/day/m^3 (675 lb BOD_5/1000 ft^3/day) (first biofilter including recirculation)
Recirculation Ratio: 1.6:1

Secondary Clarifier: Diameter - 17 m (55 ft)
Overflow Rate - 37 m^3/day/m^2 (750 Igpd/ft^2) (including recirculation)

Sludge Digestion/Dewatering Lagoon:

Depth: 1.8 m (6 ft)
Design Storage: 100 - 300 days
Design Solids Loading: 107 kg/m^2/yr (22 lb/ft^2/yr)

A number of operating problems were encountered with the waste treatment facility shortly after placing it into operation in 1971, but these have been largely overcome. Grease and fibres in the wastewater caused a clogging problem with the spray nozzles on the biofilters necessitating their frequent cleaning. A modified distribution system has been installed to alleviate this problem.

Caustic spills in the plant have occasionally resulted in wastewater pH values in excess of 9.0. These have caused damage to the biological film on the media, which requires one to two days to recover.

While the pH of the raw wastewater entering the primary clarifier is near neutral, the primary sludge pH is usually in the range of 4.3 to 4.5 when removed. This is apparently due to biological activity within the sludge. As a result, it was found necessary to install an acid resistant cloth on the vacuum filter for satisfactory sludge dewatering.

Experience has demonstrated that covers over the biofilters would be useful in preventing the deposition of airborne leaves and dirt on the media. This would also assist in retaining heat lost during winter operation.

The discharge of high concentrations of suspended solids in the treatment plant effluent was also encountered after start-up. Sodium aluminate is now added to the waste to promote the development of flocs in the secondary clarifier and improve sedimentation. The chemical is added ahead of the second trickling filter to ensure adequate mixing.

The high rate trickling filter process has performed effectively as a roughing unit, as intended, and has achieved relatively consistent BOD and suspended solids removals of approximately 85%. Final effluent concentrations of the two parameters have averaged 380 mg/L and 280 mg/L, respectively. Due to the high assimilative capacity of the receiving stream to which the effluent from this plant is discharged, more stringent effluent limitations have not been required by regulatory agencies.

The plant performance is closely monitored by five operators and a laboratory technician, with suspended solids analyses made daily and BOD_5 measured two or three times per week.

The plant was constructed in 1971 at a total cost of $1,165,000. The updated value of the plant is estimated at approximately $2.0 million and annual operating costs at $61,750, as shown in Table 18.

TABLE 18 - PERFORMANCE AND COST DATA FOR HIGH RATE TRICKLING FILTER PROCESS (PLANT I)

Capital Cost (adjusted to 1977)	$2,000,000	
Annual Amortized Cost @ 11%		$220,000
Operating Costs:		
Manpower: 3,000 hrs/yr x $10/hr	$30,000	
Electrical Power: 650,000 kW-hr/yr x $0.025/kW-hr	$16,250	
Chemicals:	$ 1,500	
Sludge Hauling:	$14,000	
Annual Operating Cost		$ 61,750
Total Annual Cost		$281,750
Cost per m^3 Treated		$0.35 ($1.58/1000 I.G.)
Cost per kg at BOD_5 Removal		$0.16 ($0.074/lb)

Plant J

The wastewater from Plant J consists of effluent from the processing of fresh fruit juices and sauces. The principal products from the plant are the following:

1) apple, pear, grape and apricot juices, and juice concentrates,

2) cherry, peach, apple, raisin, and blueberry pie filling,

3) apple sauce,

4) citrus juices made from juice concentrates.

The plant operates 24 hours/day, five days/week on a year round basis. The daily schedule consists of 16 hours of processing followed by an eight hour clean-up shift.

Wastewater from Plant J flows to an extended aeration treatment facility which also handles the wastewater from a winery and distilled liquor plant. Although only the cumulative flow data for the two plants were available, the majority of the wastewater is produced by the juice processing plant.

The total annual flow to the wastewater treatment plant is approximately 182,000 m^3 (40 MIG). Monthly flows vary from 6,800 m^3 to 27,000 m^3 (1.5-6 MIG) with large fluctuations occurring in the daily flow rate.

A schematic of the extended aeration treatment plant is illustrated in Figure 11. Effluent from the food processing plant is passed over a 40 mesh horizontal vibrating screen for coarse solids removal. Prior to entering the wet-well all wastewater is also passed through a 1.9 cm (3/4 inch) mesh coarse screen. In the wet-well provision has been made for the addition of nitrogen (aqua ammonia) and phosphorus (phosphoric acid). At the present time only nitrogen is added; there is sufficient phosphorus from the soaps in the cleaning water to supply bacterial growth requirements. Recirculated sludge is returned from the secondary clarifiers to the wet well and mixed with the raw wastewater. The aeration basin contains three 56 kW (75 hp) mechanical surface aerators.

Solids are removed from the mixed liquor in two 10.6 m (35 ft) diameter clarifiers operated in parallel. The clarified effluent is then chlorinated prior to discharge to an adjacent creek. A portion of the sludge is returned to the headworks of the plant while the remainder is thickened by centrifuging and then removed by tank truck for final disposal to land. The centrate is returned to the headworks of the plant.

Operating and design criteria for the plant are outlined in Table 19.

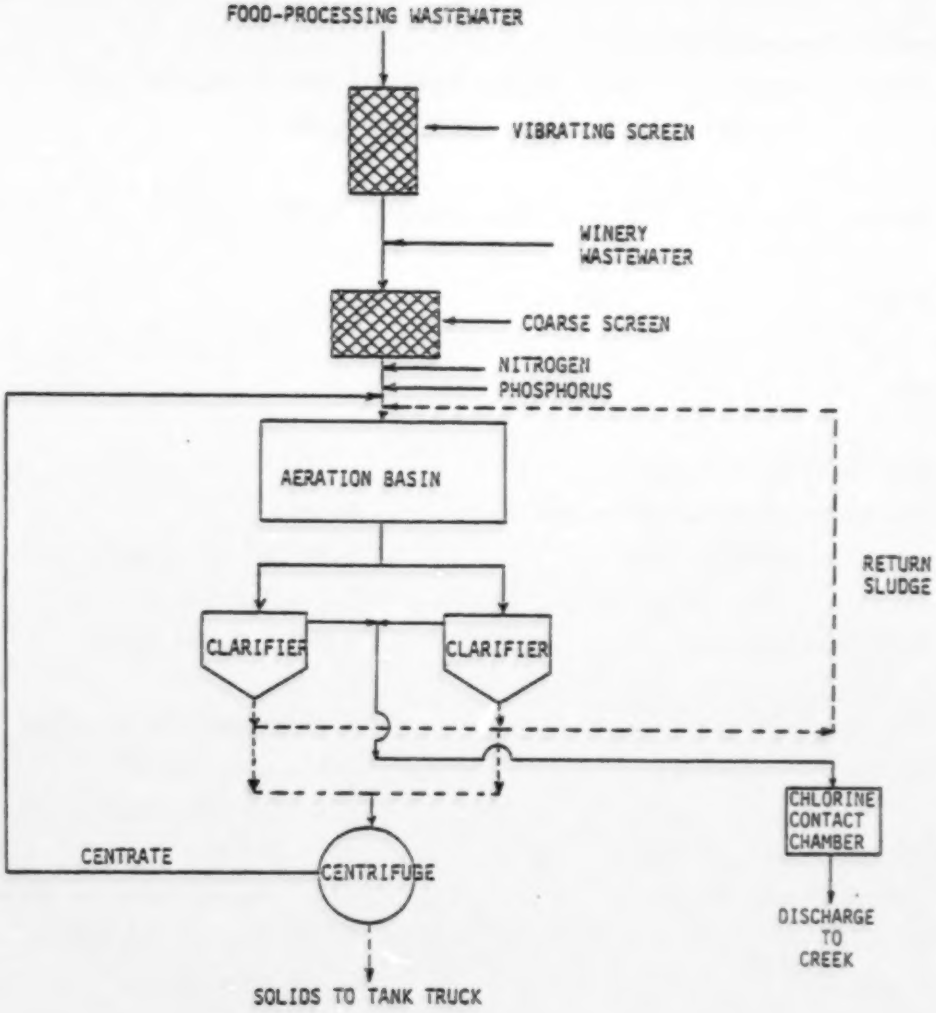


FIGURE 11 SCHEMATIC OF WASTEWATER TREATMENT PLANT (PLANT J)

TABLE 19 - OPERATING AND DESIGN CRITERIA FOR EXTENDED AERATION PROCESS (PLANT J)

Wastewater Characteristics:		
Flow:	Range:	340 - 1820 m^3/day (75,000 - 400,000 Igpd)
	Average:	700 m^3/day (154,000 Igpd)
Design Flow:		2270 m^3/day (500,000 Igpd)
BOD:		1,500 mg/L
SS:		420 mg/L
Extended Aeration Process:		
Detention Time (aeration basin):		8 days
Aeration Basin Volume:		5,675 m^3 (1.25 MIG)
Aeration Basin Depth:		3.7 m (12 ft)
MLSS Concentration		3,000 - 5,000 mg/L
Organic Loading:		0.05 kg BOD_5/kg MLSS/day
Volumetric Loading:		184 g BOD_5/day/m^3 (11.5 lb BOD_5/1000 ft^3/day)
Solids Retention Time:		30 - 40 days
Aeration Requirements:		3 mechanical surface aerators @ 56 kW ea. (30 kW/1000 m^3 of basin volume)
Clarifiers (2):		
Diameter:		11 m (35 ft)
Overflow Rate:		3.9 $m^3/day/m^2$ (80 Igpd/ft^2) at average flow
Sludge Wasting Rate:		1135 kg/day (2,500 lb/day)

Under present operating conditions the plant is achieving a BOD removal efficiency of 99% and a suspended solids removal efficiency of 96%. Effluent concentrations of the two parameters average 10 mg/L and 13 mg/L, respectively.

Operating problems were experienced initially due to ice formation on the aerators during winter operation. To alleviate this problem, warm cooling water which is normally discharged directly to the creek is diverted to the aeration basin during January and February.

Problems have also been encountered with the formation of floating sludge in the secondary clarifiers. This is caused by the adherance of sludge to the thickener machinery for extended periods of time and has been most prevalent during the cherry processing season.

Problems of biological process stability have not occurred despite the fact that the food processing plant only discharges wastewater five days each week, and the daily loadings are highly variable.

Capital and operating costs for the wastewater treatment facility are summarized in Table 20. The plant was completed in 1973 at a cost of $750,000 including land. This corresponds to an estimated 1977 value of $1,100,000. The actual 1977 operating costs reported by the plant were approximately $83,000, as shown. The total annual cost and unit costs of treatment are relatively high, considering the average wastewater flow presently being treated at this plant. This can be attributed to two factors, as follows:

1) Since the plant was designed for an average flow rate considerably in excess of that presently being treated, the capital cost incurred in its construction was appreciably higher than would have been, had a smaller plant, designed only for the current average wastewater flow, been constructed. As a capital amortization cost allowance is included in the calculation of total annual cost, and subsequently in the calculation of unit treatment costs, these costs reflect this high construction expense.

2) The operating costs presented in Table 20 are those actually reported by plant personnel, rather than as calculated for previous plants, using simply the manpower and electrical requirements of the process. Items such as the engineering cost allocation, and administration costs, which contribute significantly to the annual operating cost in this case, have not been estimated for other plants due to the highly variable nature of these costs from plant to plant and the obvious difficulty in attempting to derive a reliable estimate of this operating expense for each particular plant.

TABLE 20 - CAPITAL AND OPERATING COSTS FOR EXTENDED AERATION TREATMENT PROCESS (PLANT J)

Capital Cost (adjusted to 1977)	$1,100,000	
Annual Amortized Cost @ 11%		$121,000
Operating Costs:		
Manpower:	$27,800	
Electrical Power:	7,800	
Equipment Maintenance:	4,000	
Sludge Handling	1,200	
Plant Monitoring and Laboratory Analysis	7,350	
Engineering Cost Allocation	13,800	
Administration	15,000	
Miscellaneous	6,000	
Annual Operating Cost		$ 82,950
Total Annual Cost		$203,950
Cost per m^3 Treated		$1.12 ($5.10/1000 I.G.)
Cost per kg of BOD_5 Removed		$0.75 ($0.34/lb)

Operational staff consists of a foreman who is also responsible for the operation of the municipal sewage treatment plant, a full-time subforeman and a plant operator who spends approximately 80% of his time at the food-processing wastewater treatment plant.

Operation of the plant is monitored continuously with automatic samplers and flow metering equipment. Composite samples of influent and effluent wastewater are collected daily and subjected to COD tests. Temperature and pH are monitored daily. BOD and total suspended solids concentrations are determined twice weekly and nutrient (N & P) concentrations in the effluent are determined weekly.

Composite recirculated sludge samples are also collected regularly. Total suspended solids are determined three times per week and volatile suspended solids are determined twice weekly. The data are used to monitor sludge density to facilitate control of the sludge recirculation rate, and to monitor sludge activity in order to control the mixed liquor suspended solids concentration.

BEVERAGE INDUSTRY

Plant K

Plant K is a distillery which processes approximately 145 tonnes (160 tons) of corn, rye and barley malt per day on a 24 hour/day, 5 day/week basis. The plant presently operates only seven months per year. Main products are beverage and industrial alcohol, with fusel oil and high protein livestock feed material recovered as by-products.

Wastewater originates from equipment and floor washings, evaporator condensate, boiler blowdown, gin still bottoms and rectifier bottoms. The average daily flow of 908 m^3 (200,000 I.G.) is discharged to a 45 m^3 (10,000 I.G.) sump. From here, two pumps controlled by level switches lift the wastewater to the treatment plant.

Wastewater treatment consists of extended aeration followed by secondary clarification and a polishing lagoon, as illustrated in Figure 12. The operating and design criteria for the plant are summarized in Table 21.

Clarifier and lagoon effluents are monitored weekly by the plant operator for COD and suspended solids. A high quality effluent has generally been achieved with removals in excess of 95% and 90% for these two parameters respectively. Effluent from the secondary clarifier generally has a COD of less than 60 mg/L and this is further reduced to less than 50 mg/L in the lagoon. The lagoon reduces the suspended solids concentration in the clarifier effluent from approximately 20 mg/L to less than 15 mg/L.

Sludge is usually wasted on a monthly basis to drying beds located on the plant property.

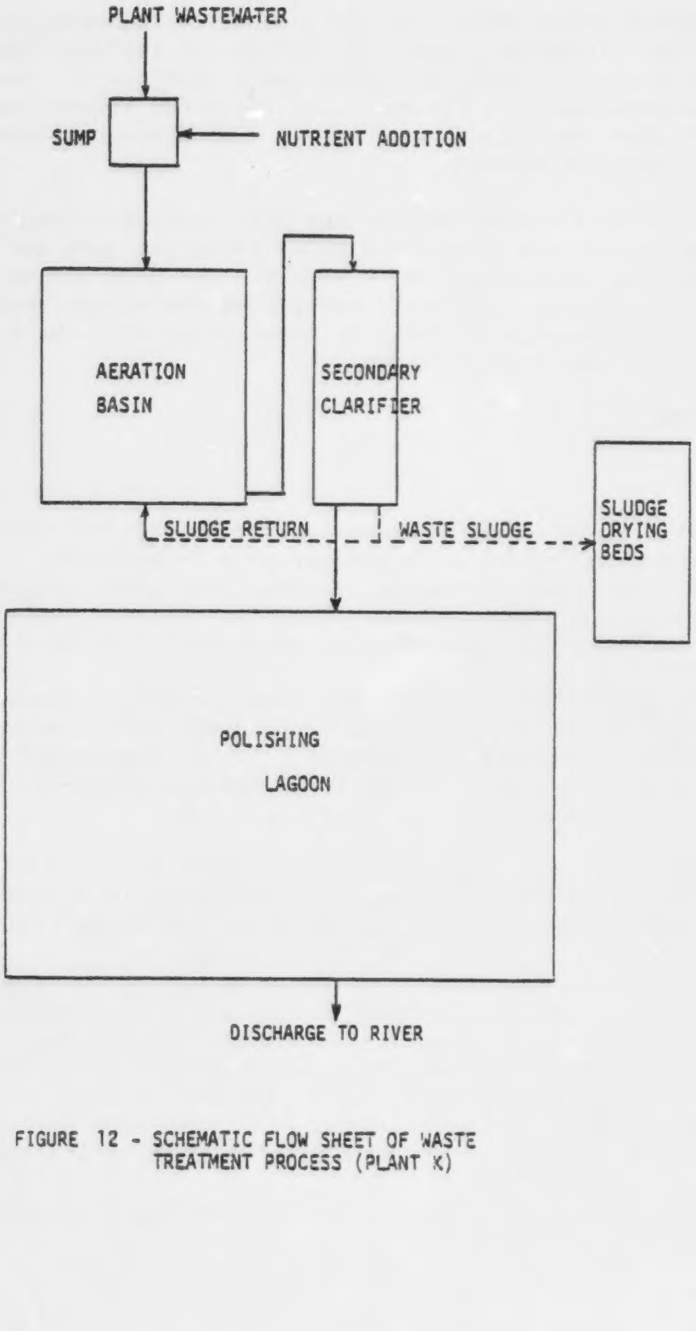


FIGURE 12 - SCHEMATIC FLOW SHEET OF WASTE TREATMENT PROCESS (PLANT K)

TABLE 21 - OPERATING AND DESIGN CRITERIA FOR EXTENDED AERATION/POLISHING LAGOON PROCESS (PLANT K)

Wastewater Characteristics:		
Flow:	Low:	23 m^3/day (5,000 Igpd) - weekends
	Peak:	2050 m^3/day (450,000 Igpd)
	Average:	1000 m^3/day (220,000 Igpd) - 5 days/week
BOD:		Average approximately 800 mg/L
COD:		1,000 - 1,500 mg/L
SS:		200 - 300 mg/L
Extended Aeration Process:		
Organic Loading Rate:		0.16 kg BOD_5 /kg MLSS/day
Volumetric Loading Rate:		800 g/day/m^3 (50 lb BOD_5/1000 ft^3/day)
MLSS Concentration:		2,000 - 8,000 mg/L
Detention Time:		24 hours
Aeration Requirements:		2 Mechanical Surface Aerators @ 19 kW ea. (4 kW/1000 m^3 of basin volume)
Polishing Lagoon:		
Depth:		1.2 m (4 ft)
Detention Time:		5 days

The wastewater has been found to be deficient in both nitrogen and phosphorus. This is compensated for by a weekly addition of 45 kg (100 lbs) of urea and 23 kg (50 lbs) of sodium dihydrogen phosphate to the wastewater sump.

It has been found necessary to chip ice from around the aerators during winter months. Some freezing problems with the clarifier have also been encountered in cold weather.

Since the distillery is operated only seven months per year, the waste treatment plant must be re-started when production commences. The start-up period usually requires from 7 to 10 days, although in cold weather this may be extended to 21 days.

Plant operation is the responsibility of a lab technologist, who spends approximately 4 to 5 hours per week monitoring plant performance and making adjustments as necessary. An additional hour per week is spent inspecting and lubricating mechanical equipment and adding the necessary nutrients.

As shown in Table 22, the estimated present value of the plant is approximately \$1,020,000. It was originally constructed in 1969 at a cost of \$490,000. Annual operating costs are estimated at approximately \$7,500.

FISH PROCESSING INDUSTRY

Plant L

Plant L is a salmon processing plant that produces fresh, fresh-frozen and smoked-fish products. In addition to salmon, the plant processes aquaculture fish, primarily rainbow trout and immature salmon. The salmon processing season runs for approximately six months with the processing of aquaculture fish occurring during the remaining six months of the year. The plant operates on a 6-1/2 hour/day, five day per week schedule.

Wastewater originates as washwater from fish cleaning and gutting operations, and as table and floor washdown water. During the salmon processing season, flows vary from 1.4 to 4.5 m^3/day (300 to 1,000 Igpd) with an average flow rate of 2.6 m^3/day (580 Igpd). While processing aquaculture fish, these increase to an average of 13.6 m^3/day (3,000 Igpd).

The wastewater treatment system is an extended aeration process as illustrated in Figure 13. Raw wastewater flows to a wet-well where grinder pumps lift it to an aeration basin. Aeration is provided by a 3.7 kW (5 hp) mechanical surface aerator. Overflow from the aeration basin then enters a clarifier. Settled sludge is returned to the aeration basin from the clarifier by means of an air lift pump. Clarified effluent is discharged to a polishing pond which acts as an exfiltration basin.

TABLE 22 - CAPITAL AND OPERATING COSTS OF EXTENDED AERATION/POLISHING LAGOON PROCESS (PLANT K)

Costs:		
Capital Cost (adjusted to 1977)	$1,020,000	
Annual Amortized Capital Cost @ 11%		$112,200
Operating Costs:		
Manpower: 6 hrs/wk x 30 wks/yr x $10/hr	$1,800	
Chemicals (nutrients):	$1,000	
Electrical Power: 50 hp x 0.746 kW/hp x 5,040 hr/yr x $0.025/kW-hr	$4,700	
Annual Operating Cost		$ 7,500
Total Annual Cost		$119,700
Cost per m^3 Treated		$0.63 ($2.85/1000 I.G.)
Cost per kg BOD_5 Removed		$0.79 ($0.36/lb)

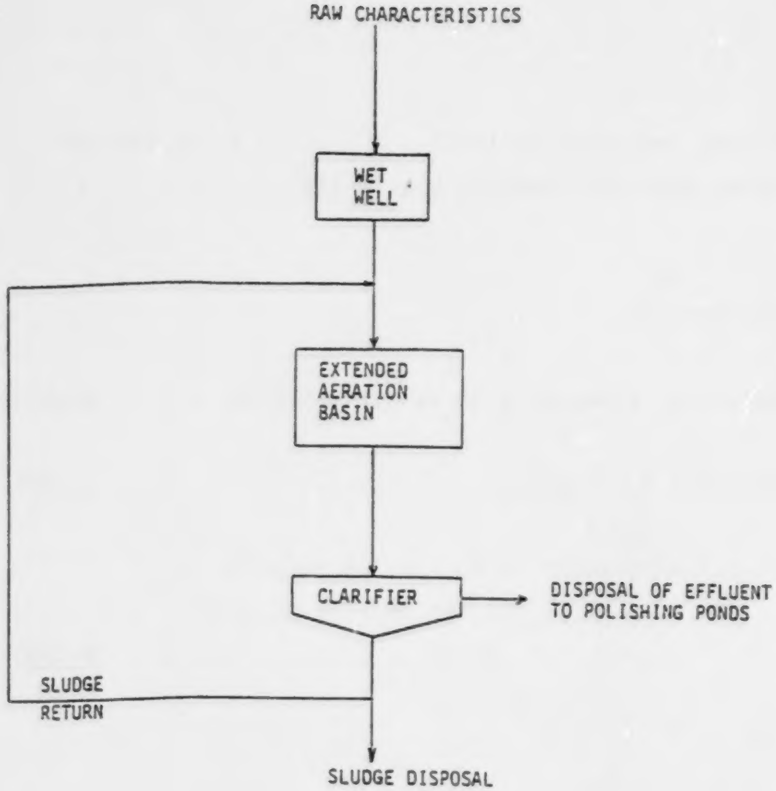


FIGURE 13 - SCHEMATIC FLOW DIAGRAM OF EXTENDED AERATION WASTE TREATMENT PROCESS (PLANT L)

Table 23 summarizes design and operating criteria for the plant.

Wastewater flows have continuously been much lower than the design flows during operation of the plant. Although BOD removal efficiencies have been within the acceptable range for an extended aeration system (i.e. greater than 90%), suspended solids removal efficiencies have been less than 65%. Apparently this has resulted from the extremely long retention times and overaeration of the mixed liquor. This results in the auto-oxidation of the biological floc, producing a pin-floc which is extremely difficult to settle.

Other operational problems of the treatment system are listed below:

1) raw wastewater pumps periodically clog with fish bones or other coarse solids.

2) float level controls in the wet-well become caked with grease.

3) the scum removal system in the clarifier has been inadequate.

In addition, the wastewater usually contains a significant number of fish eggs during the salmon processing season. The cases from these eggs become hard and cannot be broken down during the treatment process.

At the time of the field visit, an extended aeration pilot plant was being used to establish optimum loading rates and aeration requirements. Preliminary results have indicated that a 24 hour hydraulic detention time is required to achieve adequate treatment.

The treatment plant was built in 1975 at a capital cost of $80,000. The updated value of the plant is estimated at $93,000. It has not operated continuously since that time, as the pilot plant studies currently utilize most of the wastewater. Operational costs for the large plant have been minimal. It does not employ an operator, although someone has been responsible for periodically visiting the plant (approximately three times weekly). Since the plant has been relatively unused, maintenance requirements have been very low.

TABLE 23 - OPERATING AND DESIGN CRITERIA FOR EXTENDED AERATION PROCESS (PLANT L)

	Salmon Processing Season	Aquaculture Fish Processing Season
Wastewater Characteristics:		
Flow (m^3/day):		
Range:	1.4 - 4.5	7.7 - 18
Average:	2.6	13.6
BOD_5 (mg/L)	690	480
COD (mg/L)	2000	810
SS (mg/L)	500	230
Extended Aeration Process:		
Aeration Time	28 days	5.5 days
Volumetric Loading	24 g BOD_5/day/m^3 (1.5 lb BOD_5/ 1000 ft^3/day)	86 g BOD_5/day/m^3 (5.4 lb BOD_5/ 1000 ft^3/day)
Aeration Requirements	50 kW/1000 m^3 of basin volume	50 kW/1000 m^3 of basin volume
Clarifier:		
Overflow Rate	0.29 m^3/day/m^2 (6 Igpd/ft^2)	1.5 m^3/day/m^2 (31 Igpd/ft^2)
Detention Time	4.3 days	20 hours

SUMMARY OF GENERAL OBSERVATIONS

In reviewing the operation of biological waste treatment systems at the numerous food processing plants discussed in this paper, a number of recurring problems and industry concerns were identified. These are as follows:

1) treatment plant supervision
2) flow equalization
3) sludge disposal
4) nutrient addition
5) winter operation
6) treatment costs.

The above problem/concern areas warrant further discussion.

Treatment Plant Supervision

Without exception, it was found that the treatment plants operating most successfully were those which employed a trained, full-time operator.

Due to the variable nature of food processing wastewaters, the potential for upset of a biological treatment system is relatively high. Despite claims by a number of treatment equipment manufacturers and distributers, that their particular process operates with little or no supervision, very few biological treatment plants are truly capable of consistently producing an effluent of acceptable quality when treating a waste with highly variable flow and strength, without close supervision.

This is particularly true of suspended growth systems (i.e. activated sludge, extended aeration, and oxidation ditch processes) where a number of problems, such as hydraulic or organic overloading, sludge bulking, or rising sludge in the secondary clarifier may develop over a relatively short period of time, resulting in a rapid deterioration in effluent quality. These problems can only be overcome if a knowledgeable, full-time operator is on-site to identify them and take the appropriate corrective action.

A successful operator will be one who is completely familiar with the particular food processing plant and its associated wastewater characteristics. In addition, he should be knowledgeable in the fundamentals of biological treatment and be aware of the potential operating problems associated with the specific treatment process, their causes and solutions. Finally, the treatment plant operator should be familiar with the maintenance and repair of all mechanical equipment, such as pumps, motors and compressors, upon which the successful operation of the plant relies.

The operator should establish a daily schedule for monitoring the primary physical, chemical and biological parameters of the process, enabling him to assess its performance and adjust operating conditions accordingly.

It is recognized that in the case of very small food processing plants, economics may preclude the ability of the plant to retain a full-time treatment plant operator. In such cases it is recommended that the potential for employing alternative methods of treatment and disposal, requiring considerably less supervision, such as joint municipal/industrial treatment be thoroughly investigated prior to opting for on-site biological treatment.

Flow Equalization

In the course of conducting the site visits discussed in this paper, it became apparent that the majority of food processing plants operate on an 8 to 10 hour processing period per day, 5 or 6 days per week. The majority of the daily wastewater flow generally occurs at the end of this processing shift during the clean-up of equipment, floors and tables, and the dumping of the contents of product wash tanks, etc. Overnight and weekend flows are frequently negligible, made up largely of relatively uncontaminated cooling water.

Many waste treatment facilities which are sized to handle the average daily wastewater flow have difficulty providing adequate treatment for flow surges significantly in excess of this average flow. This is particularly true of some components of the treatment process such as secondary clarifiers, whose performance is so dependent on flow-through velocity. On the other hand, hydraulic and organic loadings significantly below the design rate frequently have a deleterious effect on the biological reactor stage of the process. The lack of an adequate food source for extended periods of time results in the microorganisms entering an auto-oxidation growth phase in which they consume their own cell protoplasm. This in turn results in the development of a pin floc with poor settling characteristics.

Both problems can be alleviated by providing sufficient storage capacity at the front end of the process to permit the flow surges to be temporarily held back, and fed to the treatment plant during periods of low flow.

Flow equalization can result in significant improvements in effluent quality from plants experiencing highly variable hydraulic and organic loading rates. It can also simplify the operation of the plant, and frequently results in lower capital costs for other components of the treatment process, which can be confidently sized for the average wastewater flow rate, rather than making allowances for peaking factors, etc.

One particularly effective means of providing flow equalization, which has been demonstrated by the food processing industry, is the use of anaerobic lagoons as the first stage in the treatment sequence. If properly designed, they can provide not only flow equalization, but pretreatment of the waste and an effective means of disposing and digesting biological sludge produced in the subsequent aerobic treatment steps.

Sludge Disposal

The amount of sludge which will be generated and which will require subsequent treatment and disposal should be an important consideration in selecting a waste treatment process. At some of the plants visited, sludge handling posed an enormous problem and constituted a major portion of the annual operating cost. These were generally plants at which voluminous amounts of sludge were produced, requiring haulage to an ultimate disposal site some distance away.

Those plants for which sludge handling posed relatively few problems were the extended aeration type, which had very low sludge yields, and those which had on-site sludge treatment and disposal facilities.

As discussed under flow equalization, anaerobic lagoons provide an effective means of treating and disposing of biological sludge, as well as performing other functions.

In many cases, on-site sludge dewatering and disposal by means of drying beds or spray irrigation also provides an effective and relatively inexpensive means of handling partially stabilized sludges, such as those from extended aeration plants.

In cases where insufficient land is available to permit on-site disposal of sludges, one of the most important considerations in the selection of a waste treatment process must be the amount of sludge generated by the process and the cost of disposing of the same.

Nutrient Addition

A number of food processing wastewaters are known to be deficient in either or both of the two nutrients, nitrogen and phosphorus, necessary for effective biological treatment. In some cases, these nutrients were added continuously at controlled rates based on calculated requirements determined from chemical analysis of the raw and treated waste. However, in other cases, nutrient addition amounted to the addition of "slugs" of these chemicals to the waste on a weekly basis.

The latter approach is not considered the optimum method of nutrient addition. Since the cost of purchasing these chemicals is relatively high, and the discharge of excessive amounts of nitrogen and phosphorus is undesirable from a regulatory agency's point of view, every attempt should be made to minimize the amount of supplementary nutrients required. On the other hand, if the waste is in fact nutrient deficient, then it is important to ensure that adequate amounts of nitrogen and phosphorus are present at all times to permit the microorganisms to utilize the soluble BOD_5 effectively.

This can only be done by monitoring the BOD_5, nitrogen and phosphorus concentrations of the raw and treated wastes on a regular basis, and adjusting the rate of nutrient addition accordingly. This is particularly important in industry sectors where a variety of commodities are processed throughout the year, such as fruit and vegetable processing. As the commodity changes so will wastewater characteristics and the nutrient requirements.

Winter Operation

Cold weather operation of biological treatment systems poses two specific problems; the first being a reduction in treatment efficiency due to reduced biological activity, and the second being operational problems of a mechanical nature associated with freezing conditions.

To ensure treatment plant performance conforms with regulatory agency requirements on a year-round basis, it is essential that its design be based on the most adverse conditions under which the plant will be expected to perform. Considering the highly seasonal nature of most food processing operations, the condition which should be used for design purposes may be either peak hydraulic and organic loading or minimum operating temperature (or both if the two occur concurrently). The plant size required to achieve the desired effluent quality under each operating condition should be determined and the larger size selected for design purposes.

The sensitivity of the specific treatment process to temperature effects should also be considered in the selection of a treatment system. In general, suspended growth systems such as activated sludge, extended aeration and oxidation ditches have been found to maintain superior performance in cold weather to that of trickling filters and lagoons.

Specific mechanical problems associated with winter operation were identified at virtually all plants visited, where treatment units were exposed to the air. Problems such as the freezing of mechanical surface aerators, trickling filter media and distribution equipment, and skimming mechanisms in clarifiers were commonly reported.

Some of the following design features and operating methods should be considered to alleviate these problems and improve treatment efficiency in cases where treatment plants are expected to perform under severe climatic conditions:

1) Wherever feasible, treatment units should be enclosed to minimize heat loss. While this is obviously not feasible for large aeration basins, it is considered fundamental for the successful winter operation of trickling filters and clarifiers and is absolutely necessary for rotating biological contactors.

2) The use of diffused air aeration equipment in place of mechanical surface aerators can significantly reduce winter operating problems in open aeration basins. The spray generated by surface aerators has a tendency to freeze onto aerator vanes, shrouds, and structural supports creating a heavy ice load which can lead to mechanical and/or structural failure of the equipment. This necessitates close supervision in winter months and frequent ice removal from the equipment. Diffused air aeration equipment, being totally submerged, is not susceptible to these problems.

3) It is generally advisable to minimize the amount of wastewater requiring treatment, by diverting any uncontaminated flows away from the treatment facility for reuse or separate disposal. There may, however, be some advantage in winter months to directing hot uncontaminated wastewater flows, which normally by-pass the treatment plant, through the facility, thereby elevating its operating temperature. Care must be taken, however, to ensure that this practice does not significantly reduce detention time in the plant, which may further reduce treatment efficiency.

Treatment Costs

The primary concern of any industry faced with the proposition of having to install waste treatment facilities is the cost of constructing and operating these facilities.

Unit treatment costs have been summarized for those plants for which such data could be generated, and are presented in Figures 14 and 15 as a function of plant size. As explained earlier, the unit treatment costs are based on the total annual cost which includes the annual operating cost of the plant, plus an 11% annual amortization allowance on the capital cost.

As illustrated in Figures 14 and 15, considerable scatter exists in the cost data. This scatter can be attributed to variations in wastewater characteristics, treatment processes, and effluent qualities among the plants considered, as well as other site specific variables such as construction cost.

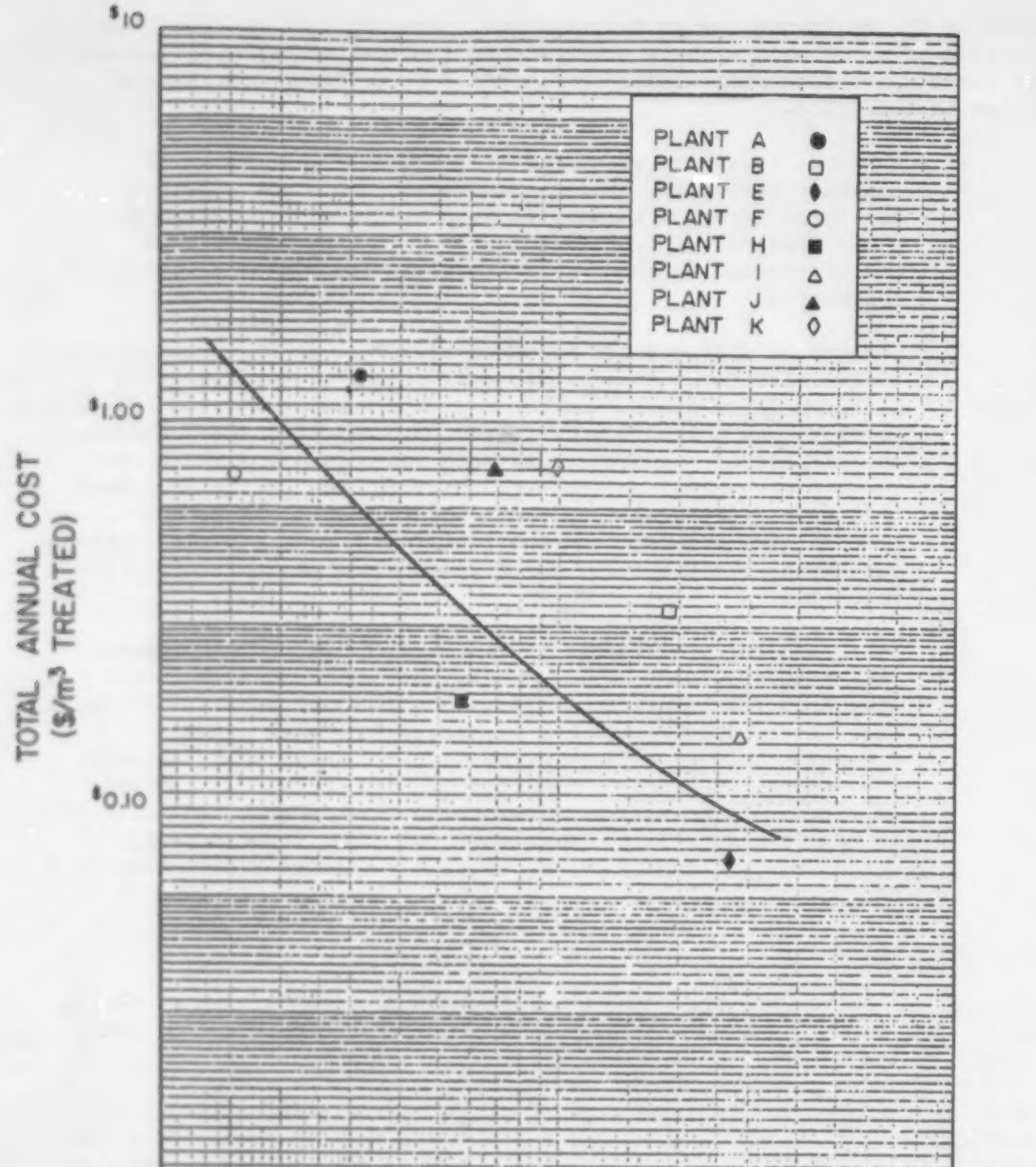


FIGURE 14 - UNIT COST ($/$m^3$) OF BIOLOGICAL WASTEWATER TREATMENT AT EIGHT FOOD PROCESSING PLANTS

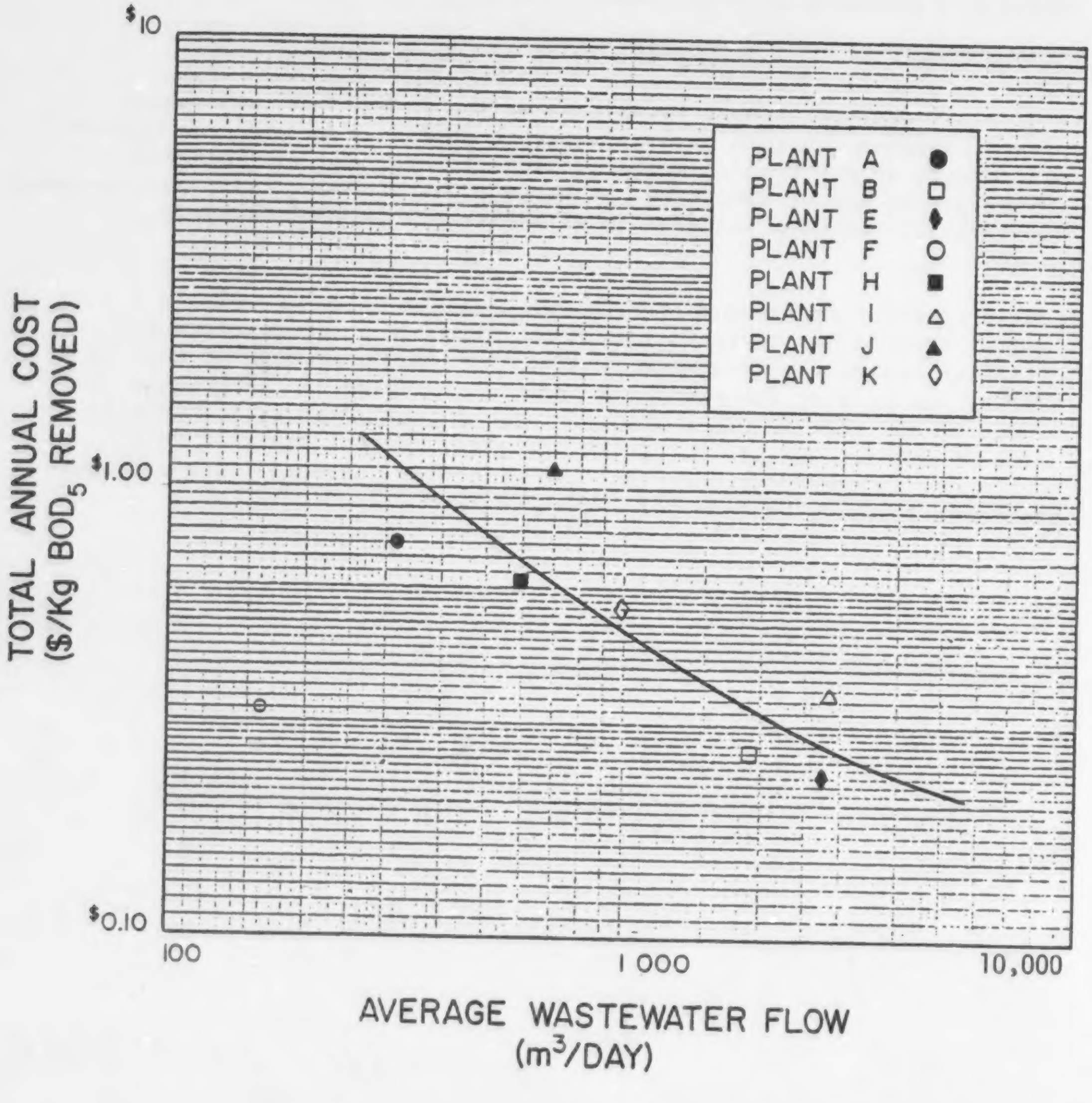


FIGURE 15 - UNIT COST ($/kg BOD_5 REMOVED)
OF BIOLOGICAL WASTEWATER TREATMENT
AT EIGHT FOOD PROCESSING PLANTS

Due to the number of variables associated with this cost data, no attempt has been made to provide the reader with a rigorous cost-effectiveness analysis of the alternative processes investigated. Rather, the data will serve to illustrate the "order of magnitude" of these costs and the trend of decreasing unit treatment costs with increasing plant size.

CONCLUSIONS

Biological waste treatment facilities at the twelve food processing plants discussed in this paper illustrate that such systems can perform effectively in northern climates if properly designed and operated. Endeavours by senior management at these plants to meet their environmental responsibilities have resulted in effective programs of wastewater management.

Such wastewater management programs necessitate more than simply a capital expenditure of funds for installation of an appropriate and effective wastewater treatment system. An ongoing commitment must be made to ensure that competent and trained operation of the process is provided, and that in-plant measures are controlled so as to minimize waste production and prevent treatment plant upsets. Only if this commitment is genuinely made can cost-effective operation of a wastewater treatment facility be assured.

THE UTILIZATION OF CHEESE WHEY FOR WINE PRODUCTION

by

G. M. Palmer* and R. F. Marquardt*

INTRODUCTION

In 1976 the United States Department of Agriculture (USDA) reported production of nearly seventeen billion kilograms (thirty-seven billion pounds) of whey in the United States as by-products of the manufacture of cottage cheese and hard cheeses such as cheddar, swiss, mozzarella, and jack. USDA estimated that seventy percent of that whey was processed into food, food ingredients, lactose or animal feed; but that thirty percent was not utilized.

The latter unutilized portion became either an environmental pollutant - being sprayed onto wasteland or dumped into rivers or streams - or an added consumer cost being cycled to municipal wastewater treatment systems for purification. It is to the utilization of that currently unused portion of the manufactured whey - sweet whey from the hard cheeses and acid whey from cottage cheese - that this report addresses itself.

BACKGROUND

Much of the reason for the cited pollution from whey lies in the economics of collecting it from small and/or isolated sources for central manufacture into useful concentrated or dried products by whey processors. To circumvent those economics and to find a way to convert that whey into a useful and marketable product at its source, Oregon State University (OSU) - working under Environmental Protection Agency (EPA) Grant No. 803301 - demonstrated the technical feasibility of fermenting supplemented whey into an alcoholic beverage. That grant was entitled, "Utilization of Cheese Whey for Wine Production."

Based on the successful completion of that work, Foremost Foods Company was granted Project No. S-8038-63010 entitled, "A Demonstration Project on the Utilization of Cheese Whey for Wine Production."

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OBJECTIVE

The objective of the Foremost project is to demonstrate the technical and commercial feasibility of producing a consumer acceptable, fermented beverage from whey. Understood, of course, is a significant reduction in environmental pollution and/or waste treatment costs.

RESULTS

To meet the objective, Foremost Foods Company, Research and Development Center, developed processing to convert either sweet or acid wheys into an alcoholic beverage giving little or no hint in its flavor as to its origin in whey. A natural fruit flavored beverage was developed from this base, and small scale consumer testing demonstrated parity acceptance when compared to a market leader in the fruit flavored wine class. Preliminary process costs indicate the beverage can be competitive in the market place. Materials balance studies demonstrated that the waste, measured in terms of BOD, from the fermentation process was significantly less than the BOD which would have resulted from disposal of the whey without fermentation.

It was demonstrated early that sweet whey or acid whey yielded to processing in similar manner. Because the greater need for whey utilization existed within the acid whey area, a major portion of our efforts were directed to acid whey; although, with nominal variation, they apply to sweet whey as well.

The processing from whey to a finished flavored product requires:

1. Clarification of the whey
2. Deproteinization of the whey
3. Supplementation to a fermentable medium
4. Fermentation
5. Clarification of the ferment
6. Demineralization
7. Formulation
8. Polishing Filtration
9. Carbonation

DISCUSSION

Processing

Let me discuss the process steps one by one, including our experiences along the way.

Clarification of the whey is required to provide a whey that is suitable for the selected deproteinization process. It is accomplished readily with centrifugal clarifiers and separators common to cheese manufacturing.

As a process step, it removes the fine cheese curds entrained in the whey as it is drawn off the cheese vat and the butterfat that is not entrapped in the cheese curd mass. This material can be re-cycled in the cheese operation in various ways, processed for other food use or routed to animal feeding operations in its concentrated form.

Once clarified, the whey is deproteinized; not by heat or chemical methods which denature the protein, but by ultrafiltration which preserves the protein in its native form.

Ultrafiltration depends upon passing all but protein molecules in the whey through a semi-permeable membrane to yield a water-clear, deproteinized whey permeate as a fermentation base. About ninety percent of the whey volume is passed as permeate when the protein is concentrated to fifty percent on the dry solids basis as the by-product. The whey protein concentrate is suitable for many food applications or for animal feeding. Several ultrafiltration systems, now commercial in various sizes, are satisfactory for this processing step.

Supplementation of the whey permeate is accomplished simply by adding a small amount of potassium meta-bisulfite as a yeast protector and stimulant and twenty-two percent of dextrose as a fermentable carbohydrate. Further supplementation is not needed as the whey provides the essential nutrients for yeast growth and fermentation.

Based upon the results of the early study by OSU, we elected to utilize the yeast Saccharomyces cerevisiae sub sp. ellipsoideus, Montrachet strain as our fermenting organism throughout the study. This yeast, provided to the substrate in commercially available active dry form, fermented the medium to a final alcohol content of ten percent in seven to ten days at twenty-one degrees Celsius (70 F) or ambient temperature.

The alcohol is derived by fermentation of the added dextrose, the lactose present in the whey not being fermented by the selected wine yeast. To ferment the lactose would have required fermentation by another type of yeast, followed by supplementation with dextrose and addition of the Montrachet yeast. A lactose fermenting yeast currently is not available in a commercial form, as is the Montrachet yeast, and would require pure culture microbiology to maintain and bring up innocula for the fermentation. To keep the processing simple and readily manageable, we elected to not ferment the lactose, but keep it intact to provide sweetening and enhance the flavor in the final product.

In the initial stage of fermentation, we provided slow, stirring agitation in stainless steel dairy processing tanks equipped with propellor agitators of the sweep variety. This provided only enough agitation to keep the yeast suspended until active fermentation began. Once actively fermenting, the yeast is kept in suspension by the active bubbling of carbon dioxide generated by the yeast.

Clarification by centrifugal or filtration methods removes the yeast bio-mass from the ferment and readies it for further processing. We found that the preferred method was centrifugal clarification, to remove the major portion of the cellular material, followed by pressure filtration, using a diatomaceous earth filter aid, to remove the remainder; resulting in a water-clear, fermented beverage base.

The ferment - or beverage base - at this point in its manufacture is predominantly salty in taste with a definite whey flavor. Attempting to formulate a fruit flavored beverage from this base led to poor results according to informal sensory panels. It was resolved that the saltiness must be removed to develop an acceptable beverage.

Two unit processes known to remove minerals from fluid streams were evaluated; these are ion exchange and electrodialysis. Ion exchange is well known in many industries as a demineralizing process; on the other hand, electrodialysis is not, but it is the basis of manufacture of a series of modified whey products widely used in the food, confection, and baking industries and is a technology utilized by the whey industry.

Testing both processes, we looked at the advantages and disadvantages of demineralizing before or after fermentation. Ion exchange before fermentation removed the saltiness but depleted the medium of essential nutrients to the point of inhibiting seriously the fermentation, whereas electrodialysis to about seventy percent ash removal reduced the saltiness markedly but did not inhibit fermentation. On the other hand, ion exchange after fermentation removed not only the saltiness, but the unpleasant whey flavors as well; whereas electrodialysis performed less well in removing the whey flavors.

Based on those results, we chose to demineralize after fermentation using an ion exchange system comprised of a strong acid cation exchanger and a weak base de-acidifier. Although not tested, it is believed on the basis of other experience - that activated carbon would effectively remove the whey flavors if electrodialysis was utilized as a demineralizing method instead of ion exchange

At this point in the process development, the flavor by mouth attribute of the beverage base is predominantly alcohol, with slight sweet and acid notes; a good base to accept flavoring.

We surveyed several versions of natural fruit flavors provided by a number of flavor suppliers as compatible with our beverage base. Comparing those flavors in our beverage base to the fruit flavored commercial wines, we selected a black currant flavor extract with other natural flavors for our beverage. Working with the supplier, three adjustments to the base flavor system were required before we were satisfied that our target was met.

Formulation studies with the several versions of the selected flavor system comprised variations in sweetening level, acid level, flavor level and carbonation level.

The current formulation developed for acceptance panel testing is characterized as follows:

Demineralized Ferment Base	75.9%
Invert Syrup	6.26%
Malic Acid	0.236%
Flavor Extract	2.42%
Water to Standardize	15.2%

This formulation, based on our acid whey fermented beverage base, provided an acceptable approximation to the commercial target wine in terms of the various flavor notes and overall balance of flavor.

The next to final processing step is a polishing filtration. This is accomplished using a microporous membrane filter similar to those used for cold sterilization processing. As a processing step, it removes the extremely fine particulates from the wine, which cause haze and sediment, and gives a fine sparkle to the appearance of the beverage.

Finally, the beverage is chilled, carbonated to two volumes of carbon dioxide and bottled ready for consumption.

Sensory Evaluation

This study was monitored throughout by extensive use of four sensory evaluation technics:

1. Informal Panels
2. Descriptive Flavor Analysis (DFA)
3. Discriminatory Panels
4. Small Scale Acceptance Panels

The informal panels were used early in the study to screen processing and flavoring systems and select the more feasible alternatives.

Descriptive flavor analysis characterized the aroma and flavor of the commercial wine and of experimental preparations, to help adjust processing and formulation toward the target. This technic uses trained panelists to quantify aroma and flavor in terms of key components and develop flavor profiles which describes the product under test. It proved very helpful in identifying off-flavor constituents in the early part of the study which aided their elimination by processing; and in adjusting formulation variables to approximate the profile of the target wine.

Discriminative panels, consisting of Research Center personnel, assisted in adjusting formulation by rating both the experimental products and the target wine in terms of too much or too little of a flavor component.

Acceptance panels were used when other sensory evaluations indicated that we had approximated the target wine in terms of critical flavor constituents and balance. Results indicated that in the eyes of the consumer as well as our in-house panels, we had approximated closely the target wine flavoring balance - although the flavors differed - by advising that the test and target products were equally acceptable.

Economics and Waste

The major portion of this presentation has been devoted to reviewing the development of processing procedures needed to produce an acceptable product. Economic and waste abatement aspects were important portions of the study and were considered throughout the product and process development. Final cost and material balances are not complete at this writing, but preliminary estimates - considered with those projections resulting from the OSU study - indicate a process and ingredient cost of fifty to sixty cents a fifth of a gallon. Material balances show that the BOD of waste streams from the process can be less than twenty-five percent of the BOD of the whey itself.

CONCLUSION

At this writing, a large scale consumer evaluation in the form of acceptance panels is being completed in east coast, midwest, and west coast locations to answer the question of commercial parity in the acceptance of the fermented whey beverage as against a market leader in the flavored wine class. Those results, together with the results reported or indicated here, will bear the proof of successfully meeting the challenge of converting cheese whey and cottage cheese whey into an alcoholic beverage acceptable in the market places of the United States.

Collectively, they will provide the cheesemaker an interesting and economic alternative to whey disposal as currently practiced, and provide the means to reduce environmental pollution due to whey.

TREATMENT OF CAUSTIC PIMIENTO WASTEWATER

by

T.M. Furlow[*] and P. Chen [**]

FOREWARD

The caustic wastewater treatment system discussed here was constructed over a three month period and started receiving wastewater in early August, 1977. Due to the light production and other construction conditions during 1977, this system was not fully evaluated during 1977.

BACKGROUND

Nabisco, Incorporated operates a food processing plant in Woodbury, Georgia approximately fifty-five miles southwest of Atlanta. This facility produces roasted peanuts, peanut butter and packaged dates year round, and canned pimientos during August, September and October of each year. Wastewater flows average around 380 M^3/day (0.1 mgd) except during pimiento season when average flows increase sharply to 2270 M^3/day (0.6 mgd). Characteristics of the raw wastewater during 1976 are shown in Table 1. The pimiento season wastewater is much stronger than the non-pimiento season wastewater, and is produced in much greater quantities. When Nabisco considered separate wastewater treatment facilities in 1973, several processes were examined. The final alternatives were activated sludge and overland flow (land application). Due to the large seasonal variation in both quantity and strength of the wastewater, and the availability of sufficient land, overland flow was selected. A fifty acre site was prepared and placed into operation. This system is shown in Figure 1. All wastewater was screened before being pumped onto the spray field. The system functioned well until 1975 when the runoff from the spray field started to increase in strength. Much of the grass died, and waterlogging of the soil was observed. By the end of the season it was obvious that corrective measures were necessary.

DEFINITION OF PROBLEM

Prior to 1975, all pimientos were peeled by a fire roasting process fueled by natural gas. Interruptions in the supply of natural gas forced Nabisco to institute caustic peeling of pimientos midway through the 1975 season.

In February of 1976, Jordan, Jones and Goulding, Inc. was retained to study the system and to determine the cause of the previous season's difficulties. A ten month study program was initiated which included an in-depth sampling program during the 1976 pimiento season. The precise problems were found to

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TABLE 1. AVERAGE CHARACTERISTICS OF RAW WASTEWATER

Characteristic	Non-Pimiento Season	Pimiento Season
BOD_5	1600 mg/1	3450 mg/1
Suspended Solids	170 mg/1	540 mg/1
Total Volatile Suspended Solids	140 mg/1	480 mg/1
pH	9.4	11.5
Flow	380 M^3/day (0.1 mgd)	2270 M^3/day (0.6 mgd)

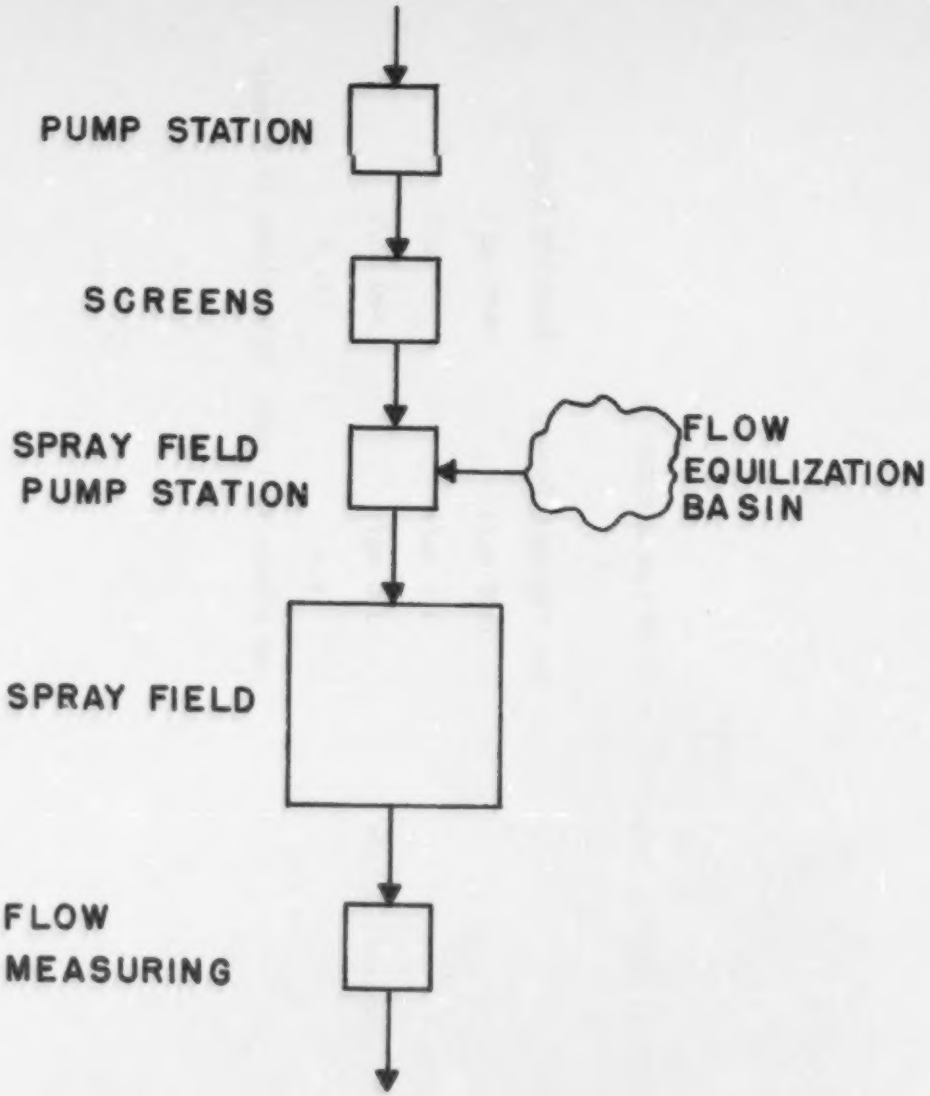

Figure I. Treatment facilities prior to 1977.

be anaerobic conditions. The waterlogging of the soil and the reduced infiltrative capacity were found to be directly related causes of the anaerobic conditions. Two Sodium Absorption Ratio (SAR) tests run on caustic wastewater samples gave results of 43 and 274. This indicated probable deflocculation of the clay soil and sealing of the soil surface. Infiltration tests revealed that the infiltration rate in irrigated areas had been reduced to zero; the infiltration rate in buffer zones was measured to be 1.9 centimeters per hour (0.75 inches per hour). It was also noted that the high solids loading was physically clogging the soil pores. The BOD_5 loading rate to the spray field increased to over 650 kg/hectare/day (580 lbs/acre/day) at an application rate of 2.16 cm/day (0.85 inches per day). The literature reports success up to 112 kg/hectare/day (100 pounds per acre per day) of BOD_5 loading. Wastewater which had not been retained in the flow equilization basin was often irrigated directly onto the spray field. The pH of this wastewater was usually in the range between 12.0 and 12.5, and damaged the grass in several areas. Wastewater which had been retained in the flow equilization basin had a pH of approximately 5.0. The detention time in the flow equalization basin was only 12 to 24 hours, but very rapid pH changes were evident. In an attempt to duplicate the pH change, raw wastewater samples were collected and seeded with varying volumes of pond effluent. This mixture was then adjusted to 11.5 with NaOH. Within one hour, the pH of the mixture was 5.1. The cause of this rapid change has been attributed to aerobic fermentation, although acid forming bacteria were likely present in the sludge in the bottom of the pond.

The study concluded that the problems encountered during the 1975 and 1976 pimiento seasons were caused not by one factor, but by a combination of the factors discussed above. It was further concluded that wastewater with the present caustic characteristics was not ammenable to treatment by the existing land application system.

DEVELOPMENT OF TREATMENT ALTERNATIVES

After determining that caustic wastewater was not suitable for treatment by land application, several courses of action were available.

(1) Change the characteristics of the wastewater by process changes;
(2) Abandon the existing overland flow system, and develop a new treatment process;
(3) Segregate the wastewater originating in the caustic peeling process, and treat it independently of the rest of the wastewater.

The first did not prove feasible because management determined that NaOH was the only practical peeling agent. The second course of action was feasible but, because of the large existing capital outlay, was more expensive than the third. The wastewater originating in the caustic peeling operation could be easily segregated, and constituted less than 10% of the total flow. It was therefore determined that the third alternative would be selected.

Before treatment processes for the caustic wastewater could be formulated, it was necessary to characterize this particular portion of the wastewater stream. Sampling and flow measurement results are presented in Table 2.

TABLE 2. CHARACTER OF CAUSTIC PIMIENTO WASTEWATER

BOD_5	20,000 mg/1
COD	35,000 mg/1
Suspended Solids	16,000 mg/1
Total Volatile Suspended Solids	13,500 mg/1
pH	12
Flow	245 M^3/day (0.065 mgd)

The exceptionally high BOD_5 and COD values indicated that an aerobic treatment system would require a high energy input. For this reason, initial considerations were directed at non-aerobic processes. One alternative was to use anaerobic ponds. These could not be located close to the production facilities. Tank trucks could be used to transport 246 M^3/day (0.065 mgd) of caustic wastewater to a suitable site during pimiento season. Another alternative was to use an activated sludge process. This alternative, however, was not feasible due to the seasonal production of the caustic wastewater. Finally, consideration was redirected toward aerobic processes despite the high energy requirements. Aerated ponds with long detention times appeared promising since suitable land was available. Recent work in North Carolina (1) indicated that the energy input could be minimized if aerobic/anaerobic ponds were utilized. In the several systems in operation in North Carolina, floating aerators with special deflector plates aerate only the top four or five feet, thus creating sharp, distinctive aerobic and anaerobic layers. The aerobic surface layer retards odors and allows use of the anaerobic process in areas where anaerobic ponds might otherwise be unacceptable.

Preliminary cost estimates were prepared and the workability of each alternative was evaluated. The aerobic/anaerobic pond alternative was selected. The capital cost of the anaerobic pond system was considerably less, but it was felt that transporting the wastewater by truck on a continuous basis was not a workable solution.

SELECTED SYSTEM

The aerobic/anaerobic system selected consists of three aerated ponds followed by a package sand filter, flow measurement, and a back up pH adjustment system, as shown in Figure 2.

The first pond is 15 feet deep and is designed to provide an aerobic layer approximately 1.2 to 1.5 meters (4 to 5 feet) deep, with the lower 3.0 to 3.4 meters (10 to 11 feet) being anaerobic. The detention time is 52 days at design flow. Table 3 gives detailed information on all three ponds.

The second pond is a complete mix basin with a 10 day detention time. Its primary purpose is to insure that all of the wastewater is aerobic before it is discharged into pond three.

The third pond serves as a holding pond and allows the wastewater to be discharged over the entire year. Two submersible pumps controlled by time clocks regulate the discharge rate from this pond. The floating aerators are intended to be used only when the water depth in this pond is greater than six feet.

The discharge from pond three is pumped into a package sand filter to insure that suspended solids from the pond are low enough to comply with EPA requirements. Alum can be added as a coagulant prior to filtration when necessary.

A backup pH adjustment system is also included which can adjust pH at either the influent to pond one, or the effluent from pond three.

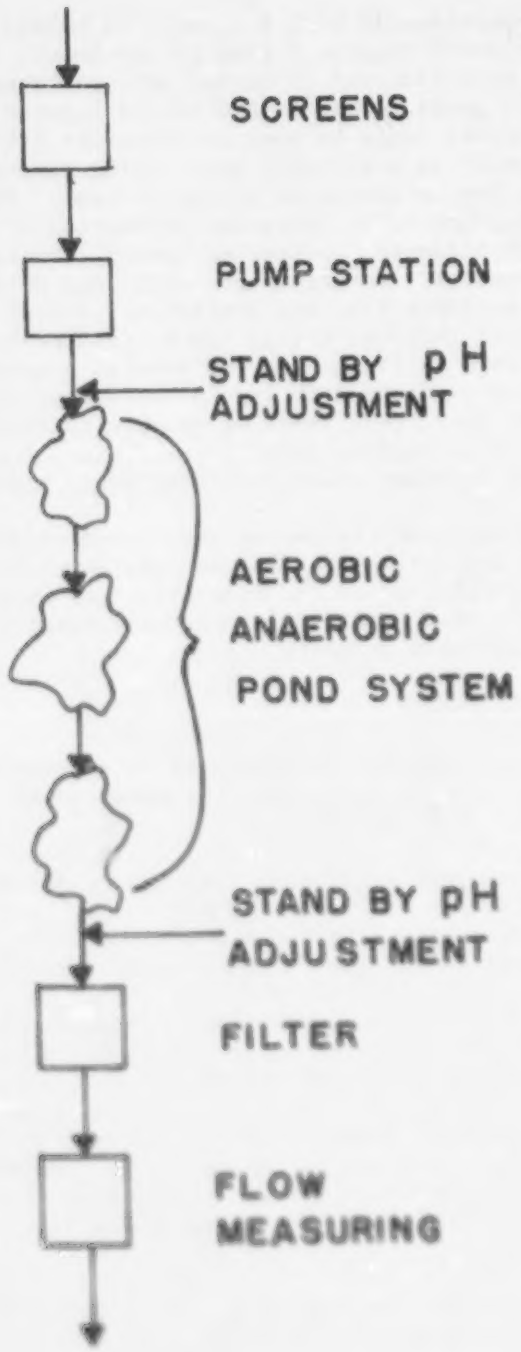

Figure 2. Caustic wastewater treatment facilities.

TABLE 3. POND DESIGN INFORMATION

Pond	Expected BOD_5 Removal (%)	Depth Meters (feet)	Volume $M^3 (ft^3)$	Detention Time Days	Pond Type
1	80	4.6 (15)	12,800 (452,000)	52	Aerobic/Anaerobic
2	50	2.4 (8)	2,460 (87,000)	10	Aerobic-Complete Mix
3	80	0-4.6 (0-15)	26,000 (919,000)	One Season	Aerobic-Holding Basin

Following the sand filter, the discharge is mixed with any runoff from the spray field. Flow is measured in a Parshall Flume prior to its discharge into surface waters.

CONSTRUCTION AND INITIAL OPERATION

Construction on the caustic wastewater treatment facilities started in May 1977. On the first day of the 1977 pimiento season, August 4th, the first pond was placed into service. In order to check the operation of the floating aerators, the basins were partially filled with water. Thus, test results from the 1977 season are not totally representative of treatment levels the system can produce. BOD_5 removal did exceed 80% in the first pond, but a detailed evaluation of the remainder of the system was not possible during the 1977 season. It is anticipated that an in-depth study program will be conducted during the 1978 season to further evaluate the operation of this system.

REFERENCES

1. Humerick, F. J., Personal conversations

OVERLAND FLOW TREATMENT OF DUCK PROCESSING WASTEWATER IN A COLD CLIMATE

by

Lloyd H. Ketchum, Jr.*

INTRODUCTION

Highly skilled personnel for design and construction as well as operation of wastewater treatment plants for small slaughterhouses and poultry processing plants is generally not available. These small slaughtering and processing operations account for a small fraction of the total slaughter, however, they do nevertheless make up a very large fraction of the total sites. These small plants are generally located in rural areas close to the growing operations and feed lots.

There is a need, therefore, to develop treatment facilities which are easy to design, simple and inexpensive to construct, and which can produce high quality effluents using relatively unskilled operators. In general, land is available since these plants are located in rural areas. Being located in scattered rural areas, however, wastewaters are often discharged into small streams and rivers or directly into the ground water. These wastes, if improperly treated, can cause serious degradation in water quality in these scattered rural areas.

The objectives of the project discussed herein are summarized as follows:

- To demonstrate the operation of an inexpensive wastewater treatment facility which will meet the 1983 National discharge limitations.
- To evaluate the use of spray runoff irrigation in a cold climate.
- To evaluate the effectiveness of batch chemical treatment directly in a lagoon for phosphate and suspended solids removal (including algae) and disinfection.
- To develop basis of design for the proposed treatment system, and to present these design details sufficiently clear to allow their use by slaughterhouse operators with little technical assistance.
- To present estimates of costs for treatment to allow economic comparison of this system to others capable of treating these type wastes.

The project is currently in progress and none of these objectives have been completed. Reported herein, however, are details of the design and construc-

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tion of these facilities and winter operation of the spray runoff irrigation plot.

The project is being conducted at Culver Duck Farm, Inc. near Middlebury, Indiana. This is a completely new processing plant. Processing was begun on November 10, 1977 at a rate of 200 ducks per day. The current rate is about 4000 ducks per week, the maximum which can be grown indoors during winter periods. To date, approximately 70,000 ducks have been processed.

The plant has been designed to minimize water use, and includes the use of a vacuum evisceration system. Wastewater volumes have been estimated at 23 L/duck (6 gal/duck). Current water use is unknown since the meter has not yet been installed. Consumption appears to be considerably higher than this estimate, primarily because production is much lower than the design capacity, which results in higher water use per duck, and the operators have concentrated on the processing operation and have not yet devoted sufficient attention to water usage. The overall effect is discharge of relatively large volumes of weak wastewaters.

WASTEWATER TREATMENT SYSTEM

Table 1 gives the basis of design and a schematic diagram of the wastewater treatment system is shown in Figure 1. A fine screen, Rotostrainer, is used to remove pin feathers, offal and other solids which may be present in the water prior to discharge to the sewer. A gravity grease separator follows the fine screen. However, heavy grease loads are not experienced because of the dry evisceration and the effectivenss of the fine screen. These solids are picked up by the vacuum system and conveyed to holding containers where they are picked up by a rendering service.

Following this preliminary treatment in the plant, the wastewater flows to the pump manhole where it flows either into the storage lagoon or is pumped directly to the spray runoff irrigation plot. During periods of processing, the pumps may be operated to apply raw wastewater directly to the spray runoff irrigation plots. During periods when no processing occurs the pumps may be operated to discharge wastewater which has undergone some stabilization during storage in the storage lagoon. This system has been designed to allow the flexibility of either operation. Both will be utilized during various operating modes throughout this study.

Two spray runoff irrigation, or overland flow, plots are used to allow two modes of operation under parallel conditions. Each is 20 m wide by 80 m long (65 ft. by 260 ft.), or 0.16 hectares (0.39 acres) in area. Loading rates and cycle conditions will be varied during the study. Current operation results in applying wastewaters ten hours per day, five days per week at a rate of 7.6 cm per week (3 inches/week).

Traditional spray runoff irrigation methods are only suited for soils with low permeabilities. This low permeability reduces contamination of ground waters and allows for additional treatment either in a lagoon as used in this study, or by recycle back to the plot during periods of low quality.

TABLE 1: DESIGN BASIS

PART A

Process	
Production	3000 ducks/operating day
Operating Days	winter 2 d/week summer 3 to 4 d/week
Live Weight	6.4 lbs/duck 2.9 kg/duck
Waste Volume	6 gal/duck 23 L/duck

PART B

Waste Treatment Facilities		
Storage Lagoon	0.46 MG 1740 m^3	
Overland Flow Plots	2 plots 65' x 260' 20 m x 79 m 4 percent slope applications 3 in/week 7.6 cm/week	 0.388 acres 0.157 hectares
Batch Treatment Lagoon	0.13 MG 490 m^3 4 weeks storage*	

*Based on summer production and 50% evapotranspiration loss on overland flow plot.

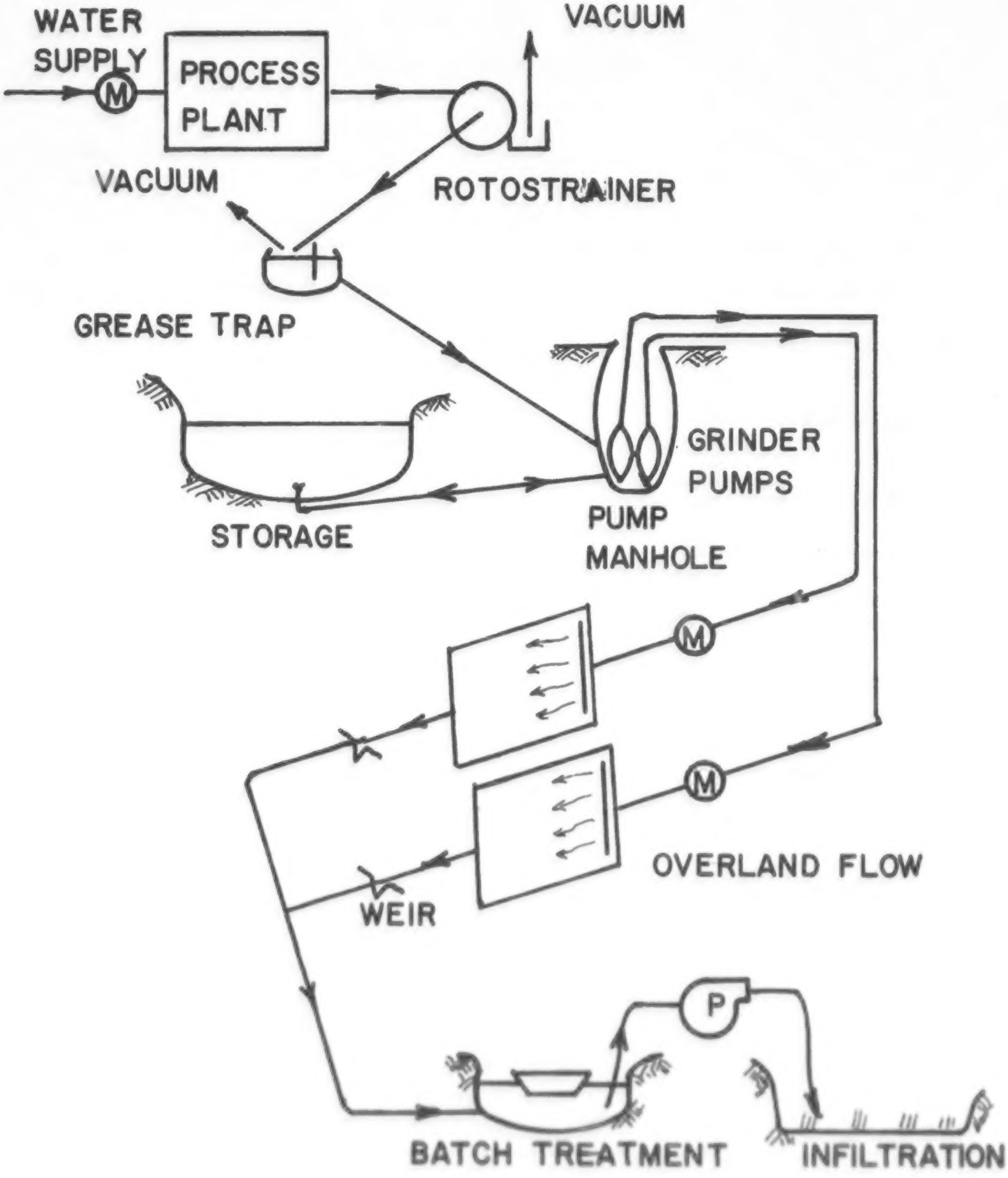

FIGURE 1: Wastewater Treatment System Schematic

Therefore, only effluents meeting effluent limitations are discharged into receiving streams or ground waters. In areas where only permeable soils exist, traditional spray runoff irrigation treatment is not possible. This study addressed this problem, and developed a method of treating wastewaters by spray runoff irrigation techniques on relatively permeable soils. The Culver Duck Farm site, according to U.S. Soil Conservation Service data, is located on a sandy loam (Oshtemo Series) with a permeability of 5 to 15 cm/h (2 to 6 inches/hour) which is much greater than that of the clays normally used for spray runoff irrigation.

To eliminate infiltration of the wastewater into the ground water at this site, a bentonite seal was constructed six inches below the top soil which was than carefully graded to provide a four percent slope. This seal essentially eliminates infiltration into the ground water, and all applied wastewater, not lost by evapotranspiration, reaches the foot of the plot. Figure 2 shows details of the construction of this spray runoff irrigation plot.

The batch treatment lagoon serves two primary functions. First, all effluents from the spray runoff irrigation site are collected until the lagoon is full. Laboratory jar test procedures are then completed to determine needed chemical dosage for phosphorous and suspended solids reduction. Using a floating mechanical aerator to provide mixing, alum is sprayed into the mixing lagoon followed by a hypochlorate solution for disinfection. After an appropriate period of mixing, the aerator is shut off and the solids allowed to settle. After appropriate analyses are conducted on the settled lagoon supernatant, and these analyses indicate an effluent of sufficiently high quality, the contents of the lagoon are discharged to the infiltration lagoon. If the lagoon supernatant has not met discharge limitations, its contents can than be mixed and additional treatment provided. The second function of this lagoon is to collect wastewater which received inadequate treatment during spray runoff irrigation. This may occur during periods of high rainfalls or during application under other unfavorable conditions. These low quality effluents can than be returned to the storage lagoon for treatment under more favorable conditions, thus preventing discharge of poor quality effluents.

MONITORING

Flow rates are monitored at three locations in the system and change in lagoon water volumes allows calculation of average flows at two other points. First, water pumped from the plant well water supply is measured to allow determination of water consumption which can be compared to the number and live weights of ducks processed. Magnetic Flosensors available from Cole-Parmer Instrument Co. equipped with a totalizer and flow rate indicator are used in the grinder pump discharge lines to indicate flow rates to each of the two spray runoff irrigation plots. Effluents from these plots are measured in a weir box using a 22-1/2° V-notch weir for low flows during normal conditions and a rectangular weir for high flows during rainfall periods. Both lagoons have been measured to allow determination of liquid volumes between any depth, thus indicating average flows for any period of time during which these depths are changing.

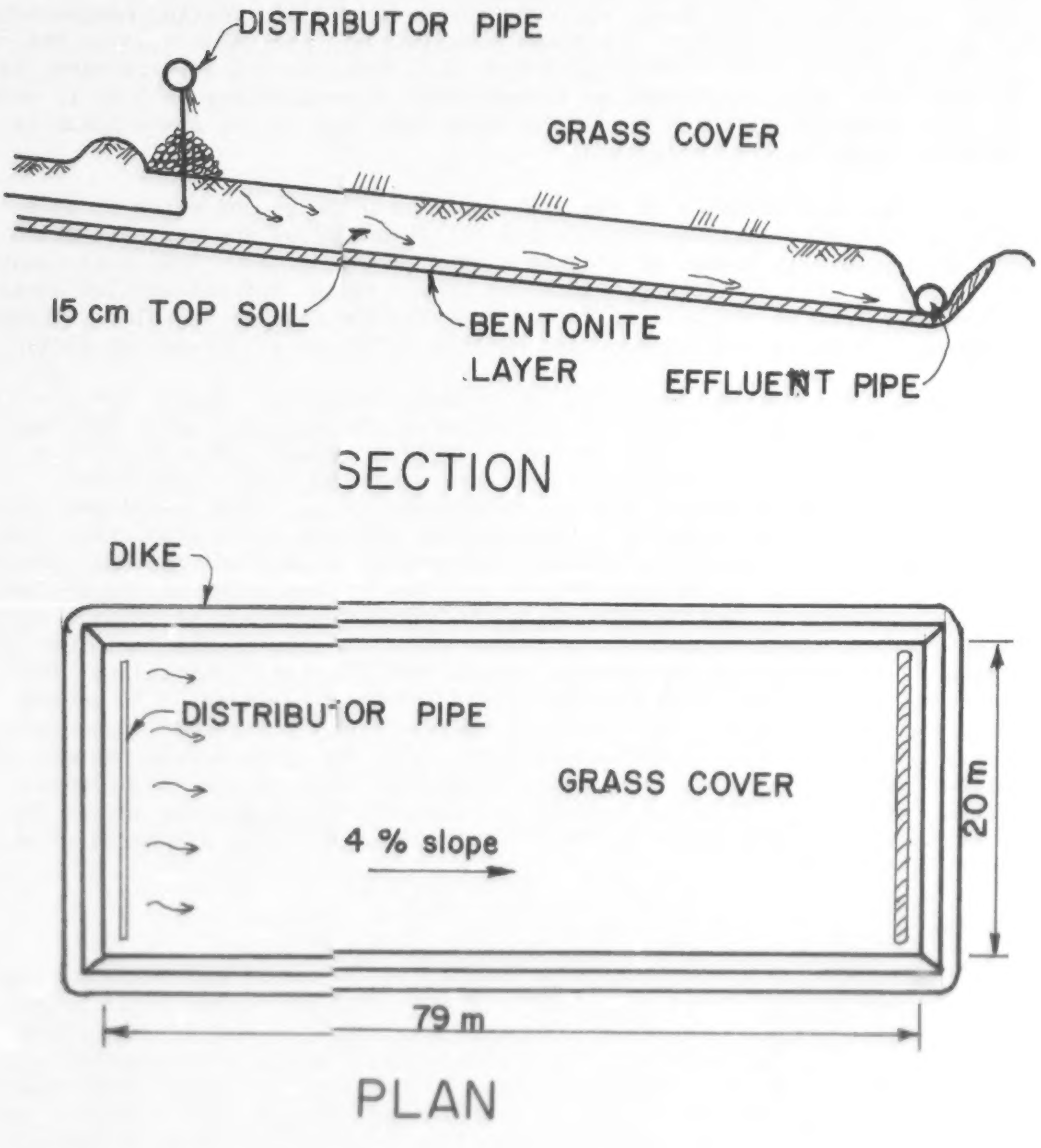

FIGURE 2: Overland Flow Plot Details

Wastewater analyses are conducted generally according to procedures outlined in Standard Methods and include the following: 5-day BOD, TOC, pH, suspended solids, ammonia, nitrate plus nitrite, Kjeldahl nitrogen, and ortho and total phosphate. These are generally taken at the influent and effluent end of each unit. In addition, temperature, dissolved oxygen, COD, oil and grease, settleable solids and fecal coliforms will also occasionally be determined.

TEMPORARY FIRST WINTER OPERATION

During the construction and start up phases of the processing plant, a time when we were also trying to complete construction of the wastewater treatment facilities, considerable difficulties were encountered which demanded the attention of the personnel assigned to both of these tasks. This resulted in delays in completion of the wastewater treatment system. These delays extended into an unusually severe winter where record snowfalls occurred. By the end of December, we had already almost reached the average annual snowfall of 67 inches. An additional 86 inches fell in January contributing to a new record annual snowfall.

The control building, used mainly to house the flow measurement equipment, was only partially completed before winter, thus preventing installation of the flow measuring equipment. The underground piping from the pump manhole to the spray runoff irrigation distributor pipe was placed in the ditches. However, before these could be backfilled the backfill material and the soil in the ditch had frozen preventing completion of the backfill operation. Several methods to allow temporary winter operation were considered. The method finally selected and installed which allowed for the operation reported herein is described as follows:

- A single grinder pump is operated continuously with discharge through one of the partially buried pipes. This continuous flow prevents freezing of the exposed pipe.

- A temporary pipe is connected to the partially buried pipe and runs above ground to and past the distributor pipe into a lagoon system used to treat wastewaters from the duck growing operation.

- A three-valve connection is made between the temporary above ground pipe and the inlet to the distributor pipe of one plot. These valves are arranged to allow restricted flow at all times through one valve into the lagoon. During periods of spray runoff irrigation, a second valve is fully opened to direct flow into the distributor pipe. The valve used to restrict flow to the lagoon is adjusted to provide the desired application rate to the spray runoff irrigation plot. At the conclusion of an irrigation period, the second valve is closed and a third valve opened which drains the distributor pipe and prevents its freezing.

Influent flow rates are determined by recording the time required to fill a known volume from each orifice in the distributor pipe. The effluent from the spray runoff irrigation plot is allowed to overflow the dike at the foot of the plot where it then passes through an earthen ditch and over a temporary 45° V-notch weir. Effluent flow rates are thus determined by measuring the depth of flow over the V-notch weir.

Wastewaters were first applied on February 22, 1978. At this time, there was about 23 cm (9 inches) of relatively densely packed snow covering the site. At least two weeks passed before overflow of the dike occurred at the foot of the plot. Wastewater was applied as indicated above resulting in an application of approximately 7.6 cm per week (3 inches per week). The snow had been removed from the area near the distributor pipe. Applied wastewater appeared to flow down the slope under the snow and accumulate at the foot of the plot behind the dike. At that point it froze. Later, as melting occurred and additional water was applied, it overflowed the dike. Snow was gradually lost from the plot until only about one half the area was covered with a layer of ice. The idle plot, adjacent to the operating plot appeared to behave essentially the same. Snow loss, flow over the dike and ice formation all appeared to be similar.

One interesting observation was the grass which appeared to be a healthy green in the areas not covered with snow or ice.

RESULTS

Occasional grab samples were taken from the influent and effluent of the spray runoff irrigation site after the first two weeks of operations. In general, two influent conditions occurs. One when pumping occurs during processing which results in raw wastewater being applied to the plot, and the other when no processing is taking place which results in water from the storage lagoon being pumped to the plot. In the first case, the influent wastewaters tended to be relatively strong with 5-day BOD's greater than 100 mg/L being common. In the second case, these wastewaters were relatively weak having 5-day BOD's between one-third and one-half this level. This is due partially to the stabilization which takes place in the lagoon but also due to dilution during the early phases of plant start up when only a few ducks were being processed using full process water flows.

The grab sample effluents from the plot were relatively weak showing 5-day BOD's of 5 to 10 mg/L. Dilution from melting snow undoubtly contributed to these low values.

Two detailed analyses of the influent and effluent of the spray runoff irrigation site were completed. One of these was taken from samples collected March 21, 1978 which was during a duck processing period, therefore, a period of application of raw wastewater. The other, March 22, 1978, was conducted during a day when no processing took place and wastewater from the storage lagoon was being treated. The results of these analyses are shown in Table 2. These data are taken from flow-weighted composite samples collected during the period of spray runoff irrigation pumping.

A mass balance, based on the average influent and effluent flow rates during the sample periods, and the composite analyses of these waters is shown in

TABLE 2: WASTEWATER CHARACTERISTICS

	Overland Flow Plot	
	Influent	Effluent
March 21, 1978 Sample	PROCESSING DAY	
5-day BOD, mg/L	170	7
COD, mg/L	250	80
$NO_3 + NO_2$, mg/L as N	0	0.01
NH_3, mg/L as N	4	4
Total Kjeldahl nitrogen, mg/L as N	33	10
Orthophosphate, mg/L as P	2.3	0.7
Total phosphate, mg/L as P	2.6	0.6
March 22, 1978 Sample	NO PROCESSING DAY	
5-day BOD, mg/L	93	24
COD, mg/L	230	45
$NO_3 + NO_2$, mg/L as N	0	0
NH_3, mg/L as N	3	3
Total Kjeldahl nitrogen, mg/L as N	23	3
Orthophosphate, mg/L as P	0.3	1.2
Total phosphate, mg/L as P	0.6	1.3

in Table 3. In general, it appears stabilization of organic matter is taking place and nitrogen removal is occurring in spite of the ice and snow cover and the relatively low temperatures. Several other grab samples taken during the two weeks preceding this study also indicated stabilization of organics and nitrogen removal were taking place. Table 4 has been included to indicate weather conditions during the period of overland flow treatment. Application first began on February 22, 1978, and these detailed analyses were taken a month later on March 21 and 22, 1978. Due to the ice formation during the previous 30 days of applications of wastewater, a considerable amount of snow and ice remained on the plot and significant amount of melting

TABLE 3: MASS BALANCE

	PROCESSING DAY		
March 21, 1978 Sample	Influent	Effluent	% Reduction
Average Flow During Sample Period L/s	0.42	0.62	increased
5-day BOD, mg/s	71	4	94
COD, mg/s	105	50	52
NH_3, mg/s	1.7	2.5	increased
Total Kjeldahl nitrogen, mg/s	14	6	57
Orthophosphate, mg/s	1.0	0.4	60
Total phosphate, mg/s	1.1	0.4	64
March 22, 1978 Sample	NO PROCESSING DAY		
Average Flow During Sample Period L/s	0.83	1.92	increased
5-day BOD, mg/s	77	46	40
COD, mg/s	191	86	55
NH_3, mg/s	2.5	5.8	increased
Total Kjeldahl nitrogen, mg/s	19	6	68
Orthophosphate, mg/s	0.2	2.3	increased
Total phosphate, mg/s	0.5	2.5	increased

was occurring, as can be seen by the effluent flow rates.

DISCUSSION

To date, the findings have been very promising. The use of the bentonite layer below the top soil in the overland flow plot extends the possible application of overland flow treatment to all areas of the country regardless of soil conditions. The bentonite layer further eliminates infiltration of applied wastewater into the ground water during treatment. Essentially all water applied and not loss through evapotranspiration can be collected at the foot of the hill for additional treatment or retreatment if it does not

TABLE 4: WEATHER CONDITIONS*

Date	Average Temp., °F	Precipitation, inches Water Equivalent,	Snow	Snow on Ground at 7 a.m., inches
Feb. 22, 1978	14	0	0	17
23	20	0.07	1.0	16
24	28	0	0	17
25	32	0.07	1.2	15
26	18	0.06	1.1	16
27	21	T	T	16
28	27	0	0	15
Mar. 1, 1978	18	0	0	14
2	13	0.07	1.0	13
3	21	0.12	3.1	16
4	15	0.01	0.5	15
5	11	0	0	15
6	26	0	0	15
7	24	0	0	13
8	24	0	0	12
9	19	0	0	12
10	28	0	0	11
11	35	0.20	T	9
12	36	T	0	8
13	35	0.36	0	7
14	38	0.45	0.4	6
15	35	T	0.1	4
16	30	T	T	4
17	25	T	T	3
18	28	0	0	3
19	34	0.75	0	2
20	37	0.03	0	1
21	40	T	0	T
22	44	0	0	T

*Based on records collected at South Bend, Indiana, National Weather Service Office, Michiana Regional Airport, which is located about 30 miles due west of the test site.

meet discharges limitations; thus, only fully treated wastes are discharged to receiving water or ground surfaces for infiltration into the ground waters.

The few operating results we currently have under winter conditions also appear favorable. Stabilization of organics and nitrogen removal both appeared to be occurring under cold climate conditions. Thus, overland flow treatment can be an alternative considered not only for areas of any soil condition, but even in areas of cold climate.

Additional phases of the overland flow study will be directed toward development of more favorable operating conditions during these winter periods. One approach we plan to consider is elimination of the use of storage before overland flow treatment. Thus, we will apply the raw (warm) wastewater during processing operations. In our case, this is typically during two consecutive 10-hour day periods each week during winter operations. For other systems when operation is more nearly continuous, we would propose several parallel operations sequenced to provide similar treatment. The warm raw wastewaters would be applied to the overland flow plot and continually recycled from a small lagoon at the foot of the plot to the top until a suitable effluent was obtained. Other operating and loading procedures will also be considered to attempt to develop operating procedures to allow winter operation, or to determine under what conditions winter operation must be discontinued and storage provided.

ACKNOWLEDGMENT

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ECONOMICS OF STARCH AND ANIMAL FEED PRODUCTION FROM CULL POTATOES*

by

J. R. Rosenau, L. F. Whitney, and J. R. Haight**

ABSTRACT

A finalized process for production of starch and animal feed pulp, high protein powder, and juice concentrate from cull potatoes is presented. Economic evaluations are presented for the process and an option applicable if the plant is located near a ruminant feedlot.

INTRODUCTION

Processes for upgrading cull potatoes to starch and animal feed by-products have been discussed by the authors at previous symposia (1) (2). By additional laboratory (3) and pilot plant experience (4), these processes have been tuned to the finalized processes shown in Figs.1 and 2 and briefly outlined below. An economic evaluation follows which suggests that reasonable returns on investment are possible even under recent dramatic price increases in fuel and equipment (M & S Index of 518 as opposed to only 344 in 1973) (5).

STARCH PROCESSING

As shown in Fig. 1, cull potatoes are washed with recycled water and ground with 250 ppm SO_2 in a hammer mill using a screen with 1.6 mm (1/16 inch) openings. The slurry is screened in a two-stage system with recycled juice. Most of the cellulosic material (pulp) remains above the 140 mesh screen while juice and starch pass through. The pulp is dewatered in a screwpress and dried in a continuous tray drier using waste heat from the juice processing system.

The starch/juice slurry is pumped into an elutriating-type liquid cyclone which has an extra inlet near the underflow outlet. Starch is spun to the underflow and the overflow juice recycled to the screening system. Excess juice is forwarded to the regenerative plate heat exchanger shown in Fig. 2.

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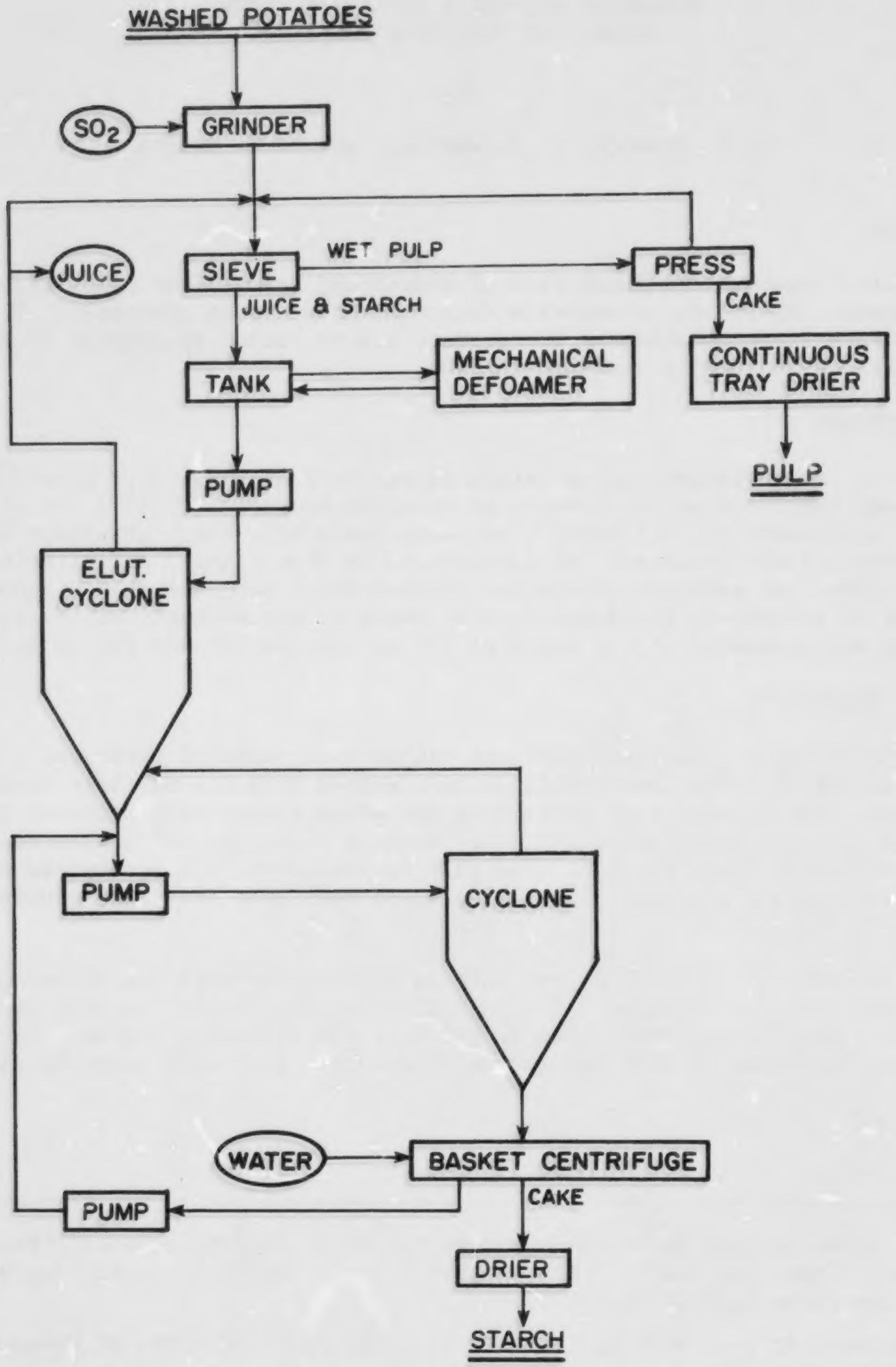

Figure 1. Starch processing flowchart.

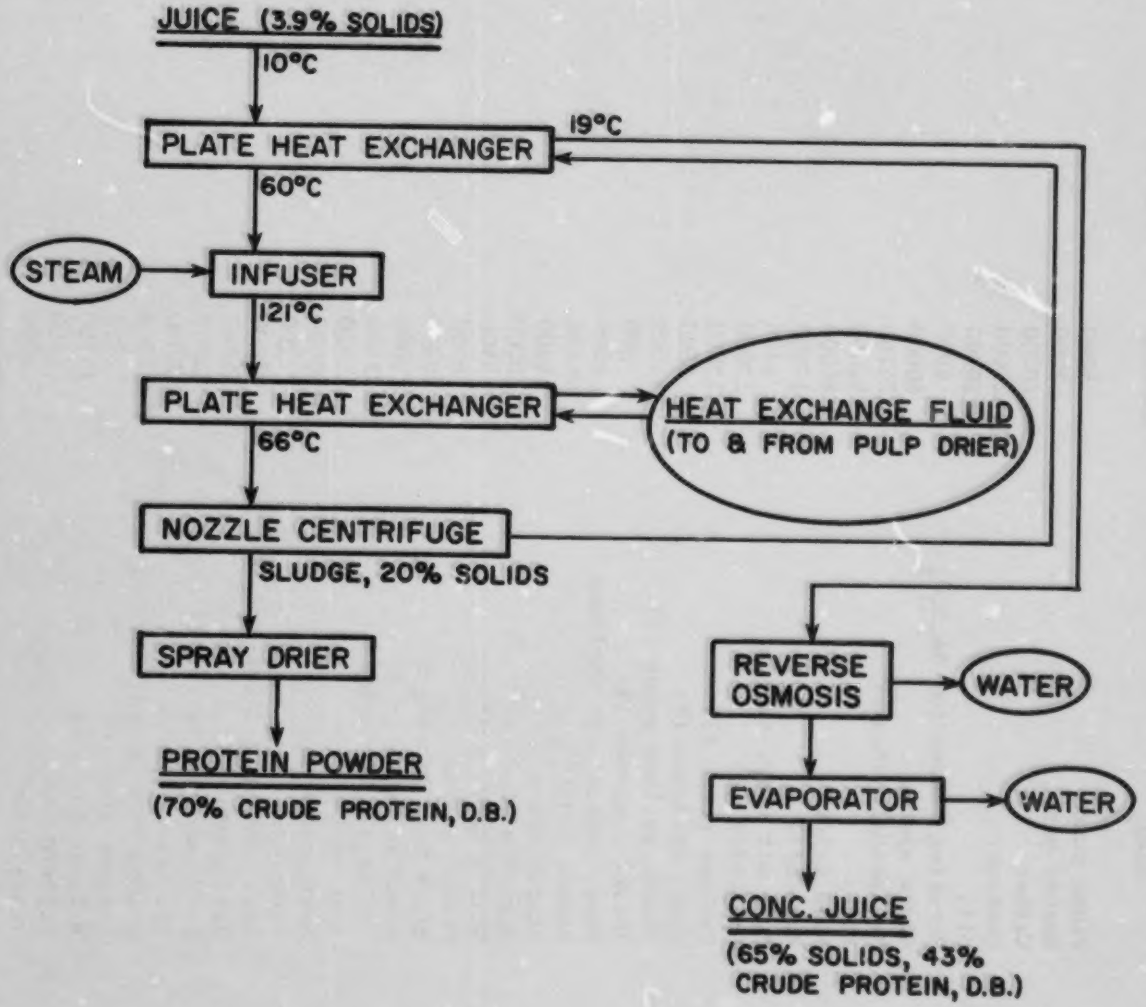

Figure 2. Juice processing flowchart.

TABLE 1. ESTIMATED FIXED CAPITAL INVESTMENT FOR PROCESSING 500 TONS OF CULL POTATOES PER 20-HOUR DAY

ITEM	COST, $	COST, $
Flume pump	5000	
Washer pump	3000	
Washer	20000	
Destoner	20000	
Mill	50000	
Metering feeder for $Na_2S_2O_5$	4000	
Sieve system	60000	
Mechanical defoamer	24700	
Press	50000	
Pulp drier	60000	
Pulp mill	10000	
Pulp air conv. system	5300	
Pulp bins (2)	10000	
Cyclone pumps (5)	15000	
Elut. cyclones (8)	5600	
Thick. cyclone pumps (5)	15000	
Thick. cyclones (4)	800	
Pump, centrif. to cyclones	1000	
Basket centrif.	98800	
Starch drier	16800	
Starch mill	10000	
Starch conv. system	5500	
Starch screen	6000	
Plate heat exchanger	20000	
steam injector	2000	
Boiler (12000 lb/hr)	25400	
Fuel tank	16900	
Nozzle centrif.	100000	
Spray drier	23700	
Rev. osmosis modules	87000	
Rev. osmosis feed pump	15800	
Rev. osmosis cir. pumps (3)	12000	
Evaporator	118600	
Concentrate pumps (2)	8000	
Concentrate tank	16900	
Balance tanks (4)	25200	
Protein bin	5000	
Truck scale	9500	
I. Total Process Equipment		982500
II. Installation (30% of I)		294800

TABLE 1 (continued)

	ITEM	COST, $	COST, $
III.	Piping, Wiring, and Control Systems (40% of I and II)		510900
IV.	Engineering and Contractors' Fees (20% of I, II, and III)		357600
V.	Contingencies (15% of I, II, III)		268200
VI.	Trucks		117000
	Concentrate truck	70000	
	Protein truck	40000	
	Pickup truck	7000	
VII.	Land		40000
	Office	35000	
	Incoming storage	63800	
	Process area	168000	
	Warehouse	60000	
VIII.	Buildings total		326800
IX.	TOTAL FIXED COSTS		2897800

Starch leaving the underflow cyclone outlet is thickened with a second liquid cyclone before passing to an automatic batch basket centrifuge for washing and dewatering. Liquid from the basket centrifuge as well as that removed by the thickening cyclone pass into the elutriation inlet of the first cyclone to separate "brown starch" from the starch. Attempts to eliminate the thickening cyclone or to add an elutraition inlet to it have not proven as successful as the scheme shown. Drying of the starch cake leaving the centrifuge should be done in a flash drier for maximum whiteness. Hunter L values of 92 (which should be sufficiently white for most purposes) have been consistently achieved in later pilot plant runs even with very low starch content potatoes and drying in a tray drier at 110C. Proper washing of raw potatoes is also important for maximum whiteness; an industrial washer, coupled with finer control of the elutriation flow rates, should improve whiteness even further.

JUICE PROCESSING

As shown in Fig. 2, juice is heated to 60C in a plate-type regenerative heater and then to 121C by steam injection. This coagulates about 35% of the crude juice protein so that it can be removed as a 20% solids (70% protein, d.b.) sludge by a nozzle-type disk centrifuge and dried in a spray drier. The remaining deproteinated juice (still at 43% crude protein, d.b.) is concentrated by reverse osmosis to 10% solids and by multiple-stage evaporation to 65% solids. It is stable in this condition and should be useful as a molasses substitute for ruminant feeding.

ECONOMIC EVALUATION

Estimated capital costs based on references (5)-(9), personal estimates, and telephone calls to selected suppliers are shown in Table 1. Table 2 shows annual costs and returns assuming the plant is run for 200 days for 20 hours per day. Also shown is the first-year return on investment (R.O.I.) at 40.1%.

LIVESTOCK OPTION

If the processing center is located near a ruminant feedlot of at least 2500 dairy cows or its equivalent (or vice versa) the pulp and concentrated juice from the reverse osmosis system can be used directly without drying or vacuum concentration. The water in the concentrate would be substituted for the normal daily water intake of 15 gallons per animal. The concentrate would contain all the protein required by the animals. The pulp drier and the vacuum evaporator as well as some ancillary equipment are eliminated by this option which would require trucking of 46 tons of wet pulp and 140 tons of concentrated juice from the plant to the feedlot daily.

The cost figures for this option are shown in Tables 3 and 4 and yield a 43.9% R.O.I. under the assumption that the feedlot would pay for the feed values in the pulp but not for that in the concentrated juice.

TABLE 2. ANNUAL COSTS, INCOME, AND R.O.I.

ITEM	COST OR INCOME,$
Rev. Osmosis module replacement	41800
Direct labor (10 months, 3 shifts of 5)	184600
Indirect labor (12 months, 1 shift of 7)	140000
Potatoes (at $0.75/cwt.)	1500000
Oil ($13.40 per barrel, 75% effic.)	152600
Electricity ($0.025 per kwhr)	27700
Maintenance (land and buildings at 2%)	7300
Maintenance (equipment at 6%)	151900
Taxes and insurance (3% at fixed costs)	86900
Depreciation on buildings (4%)	13100
Depreciation on equipment (10%)	253100
Interest on working capital	20000
General plant overhead (50% of maintenance and direct labor)	171900
I. Total Costs	2750900
Starch ($0.10 per pound)	3044000
Pulp ($100. per ton)	309200
Protein ($215. per ton)	223600
Conc. juice ($78. per ton)	335400
II. Total Income	3912200

III. R.O.I.: 40.1%

TABLE 3. ESTIMATED FIXED CAPTIAL INVESTMENT UNDER LIVESTOCK OPTION

	ITEM	COST, $
I.	Equipment: Same as Table 1 less pulp drier, hammer mill, conv. sys., and bins; less evaporator; use of smaller sizes of boiler and fuel tank; but with larger conc. juice tank.	771700
II.	Installation (30% of I.)	231500
III.	Piping, wiring, and control systems (40% of I and II)	401300
IV.	Engineering and contractors' fees (20% of I, II and III)	280900
V.	Contingencies (15% of I, II, and III)	210700
VI.	Trucks: Same as Table 1.	117000
VII.	Land	40000
VIII.	Buildings (somewhat smaller processing area than used in Table 1).	296800
X.	Total Fixed Costs	2349900

TABLE 4. ANNUAL COSTS, INCOME, AND R.O.I. FOR LIVESTOCK OPTION

ITEM	COST OR INCOME, $
Rev. osmosis module replacement	41800
Direct labor (10 months, 3 shifts of 5)	184600
Indirect labor (12 months, 1 shift of 7)	140000
Potatoes (at $0.75 per cwt.)	1500000
Oil ($13.40 per barrel, 75% effic.)	65700
Electricity ($0.025 per kwhr)	25800
Maintenance (land and buildings at 2%)	6700
Maintenance (equipment at 6%)	120800
Taxes and insurance (3% of fixed costs)	70500
Depreciation on buildings (4%)	11900
Depreciation on equipment (10%)	201300
Interest on working capital	20000
General plant overhead (50% of maintenance and direct labor)	156000
I. Total Costs	2545100
II. Total Income: Same as Table 3 but less income from conc. juice	3576800
III. R.O.I.: 43.9%	

SUMMARY

It can be seen from Tables 2 and 4 that income from starch is critical and departures from the assumed $0.10 per pound (18% moisture) will have a great effect on R.O.I. Thus, a company planning expansion into this area should investigate carefully how the price of various unmodified starches will vary in coming years as they can be modified in several ways to meet many of the traditional uses of potato starch.

The economics discussed in this paper are based on a plant processing 500 tons of potatoes per day (20 hours) of a 200-day season. Various estimates have placed cull production as 10% of the crop, i.e., somewhat over a million tons of cull potatoes annually. The plant described would thus process about one tenth of the nation's cull potato production and would appear to be the largest practicable. This is especially true in light of recent advances in potato-based products such as flours and granules which upgrade small potatoes to food use.

On the other hand, the 76 tons of starch produced by the described plant is small when compared to corn starch plants in this country or potato starch plants in Europe. Reducing the plant size would reduce the R.O.I. which is already borderline (although still acceptable, especially for a farmers' cooperative) for new plant development.

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NITROGEN FIXING BIOMASS FOR AEROBIC TREATMENT OF SOFT DRINK BOTTLING PLANT WASTEWATER

by

P. Y. Yang* and I. S. Ting**

INTRODUCTION

In order to achieve satisfactory biological treatment of wastewater, the wastewater should contain sufficient carbon, nitrogen, phosphorus, and trace minerals to meet the metabolic requirements for cell growth. For most food processing wastes, nutritional balance is not a problem since there usually is enough carbon, nitrogen, phosphorus, and trace minerals. However, certain food processing wastewaters, such as those from sugar refineries, tapioca processing, pineapple canning and processing, and soft drink bottling processing, have a deficiency of nitrogen which must be added in proper amounts to achieve appropriate biological treatment of these wastewaters. Modification of the activated sludge process for the treatment of nitrogen-deficient organic wastewaters has been studied (1) (2) in order to achieve effective COD removal, to reduce the additional cost of nitrogen and to minimize the nitrogen concentration in the effluent.

Azotobacter sp have long been used as non-symbiotic, free nitrogen fixing bacteria to improve the yield of a crop (3). This concept has been introduced for the treatment of nitrogen-deficient synthetic wastewater by using Azotobacter Vinelandii (4). Therefore, the application of this concept for the treatment of nitrogen-deficient food processing wastewater and development of necessary design criteria for the operation of this system will certainly be useful for the reduction of operational cost and achieve the necessary effluent quality. The Sermsuk Company, Ltd., Bangkok, Thailand, has operated an activated sludge treatment plant with an averaged raw wastewater flow rate of 52 m^3/hr (13,738 gal/hr) and COD of 1150 mg/l for many years. Handling of this soft drink bottling plant wastewater has created problems as follows: addition of inorganic nitrogen, bulking sludge, and excess sludge handling. In order to improve and modify the existing performance of the treatment plant, studies were carried out for several years at the Asian Institute of Technology, Bangkok, Thailand (2) (5) (6) (7). However, it was felt that further study on the reduction of nitrogen addition and excess sludge production would also be useful if such a process could be developed.

MATERIALS AND METHODS

Wastewater collected from the soft drink bottling plant of the Sermsuk Company, Ltd., was used for the present study. In order to enrich the growth

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medium, other minerals were added as shown in Table 1. This medium was used for the development of appropriate nitrogen fixing biomass (NFB) which could be used for the study of feasibility and kinetic behavior of batch and once-through continuous cultures. Apparatus for these two cultures are shown in Figure 1. Volume of aeration chamber for batch and continuous cultures is 1.5 and 6.0 liters,respectively.

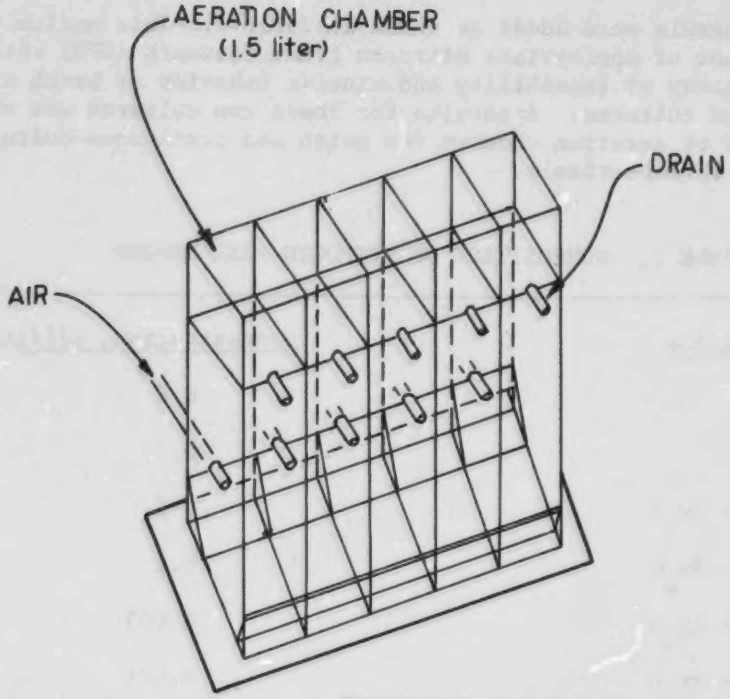
TABLE 1. COMPOSITION OF NITROGEN FREE MEDIUM

Composition	Concentration, g/liter
K_2HPO_4	0.8
KH_2PO_4	0.2
$MgSO_4 \cdot 7H_2O$	0.2
$CaSO_4 \cdot 2H_2O$	0.1
$FeCl_2 \cdot 4H_2O$	0.003
$NaMoO_4 \cdot 2H_2O$	0.001

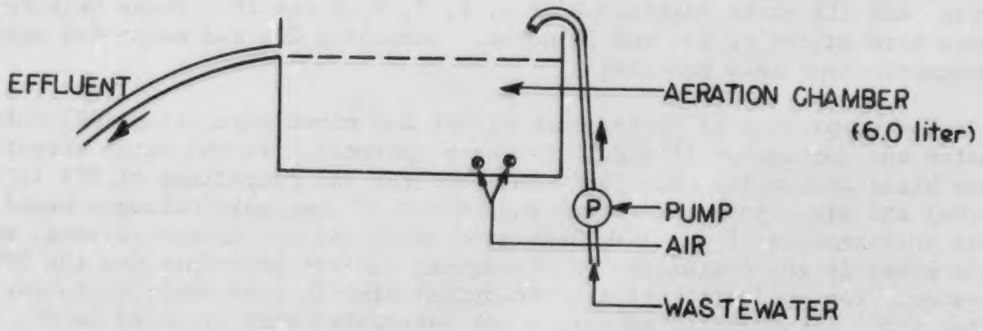
The acclimatized NFB culture (2 milliliters) was transferred to six of 200 milliliters of soft drink bottling wastewater with mineral medium (nitrogen free) and different initial pH of 5, 6, 7, 8, 9 and 10. These cultures were then aerated for 9, 16, and 30 hours. Remaining COD and suspended solid concentrations were measured.

For the comparison of performance of NFB and mixed population (MP) cultures, batch and continuous flow cultures were operated. In the batch operation, two kinds of studies were conducted; one for the comparison of NFB (nitrogen free) and mixed population with supplement of inorganic nitrogen based on the performances of pH, TKN, suspended solid and COD concentrations, while the other is the evaluation of biological kinetic constants for the NFB system. For evaluation of the biological kinetic constants, different initial COD concentrations of soft drink wastewater were prepared as 50, 100, 200, 400, 600, 800, 1000 and 1300 mg/l. Filtrate COD and suspended solid concentrations were measured. For the operation of continuous flow (without sludge recycle) system, different dilution rates of 1/2, 1/3, 1/4, 1/6, 1/8 and 1/13 hour^{-1} were operated. Steady-state COD and suspended solid concentrations were measured.

The analyses of concentration of suspended solids, chemical oxygen demand (COD), and total nitrogen (Kjeldahl) were followed according to "Standard Methods" (8).



BATCH CULTURE



CONTINUOUS CULTURE

FIGURE 1, APPARATUS FOR NFB CULTURE

RESULTS AND DISCUSSION

In the present study, the initial NFB was acclimatized with pH 7.0 with nitrogen-free soft drink wastewater. Once the NFB was developed, the determination of optimal range of pH followed. The result is shown in Figure 2. Apparently, the optimal range is between 6 to 9. This also indicates that the NFB can be more active with high pH than with low pH.

The general performance of NFB and MP systems in the batch operation is shown in Figure 3. It indicates that both systems perform at the same efficiency of COD removal but differ in the accumulation of suspended solid concentrations and TKN contents. In the NFB system, less accumulation of suspended solid concentration and lower TKN content results as compared to the MP system with the same initial COD concentration. Apparently, the biological kinetic behavior of the NFB system has merit. As shown in Figures 4, 5 and Table 2, the yield value (Y), maximum growth rate (μm) and saturation constant (K_s) are different in both systems. Lower value of cell yield in the NFB system would certainly represent an important parameter for excess sludge handling as practiced in the conventional activated sludge process. In addition, the lower value of TKN in the effluent of the NFB system is very important since higher content of nitrogen concentration in the effluent will cause an eutrophication problem in the receiving stream.

TABLE 2. COMPARISON OF BIOLOGICAL KINETIC CONSTANT

Biological Kinetic Constants	NFB System	MP System (9)
μm, hour^{-1}	0.30	0.62
K_s, mg/liter	260	125
Y, mg/mg	0.137	0.53

In order to observe the operational characteristic of continuous flow operation, these two systems were operated as once-through continuous completely-mixed flow with different dilution rates. The results are shown in Figures 6 and 7. According to the dilute-out curve shown in Figure 6, the NFB system shows no wash-out of suspended solid even when 0.5 hour^{-1} of dilution rate is provided. This does mean that the volume of the secondary settling chamber can be drastically reduced for handling of the secondary sludge produced from the aeration chamber. Furthermore, the effect of dilution rate on the cell yield values and COD removal efficiency for these two systems are shown in Figure 7. It can be seen that the NFB system provides nearly the same COD removal efficiency with the MP system with much lower cell yield values at different dilution rates as compared to the MP system. Apparently, the NFB system utilizes a greater portion of the substrate as an energy source for the nitrogen fixation process rather than synthesis of

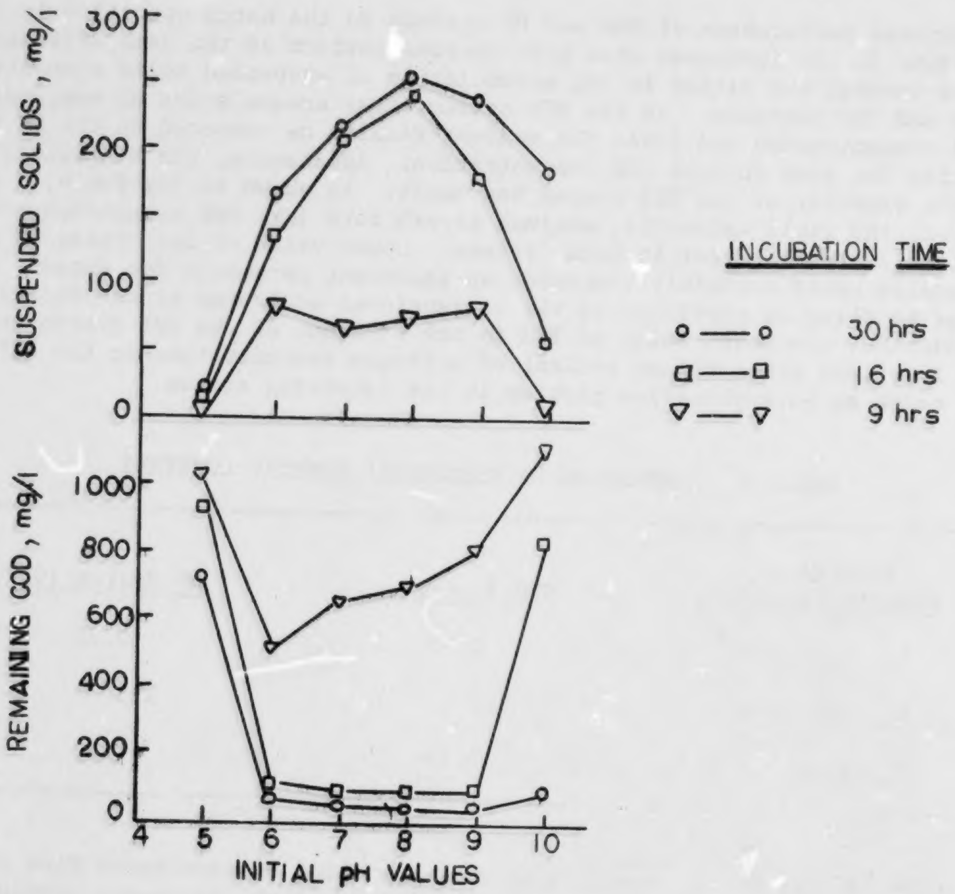


FIGURE 2, OPTIMAL pH DETERMINATION

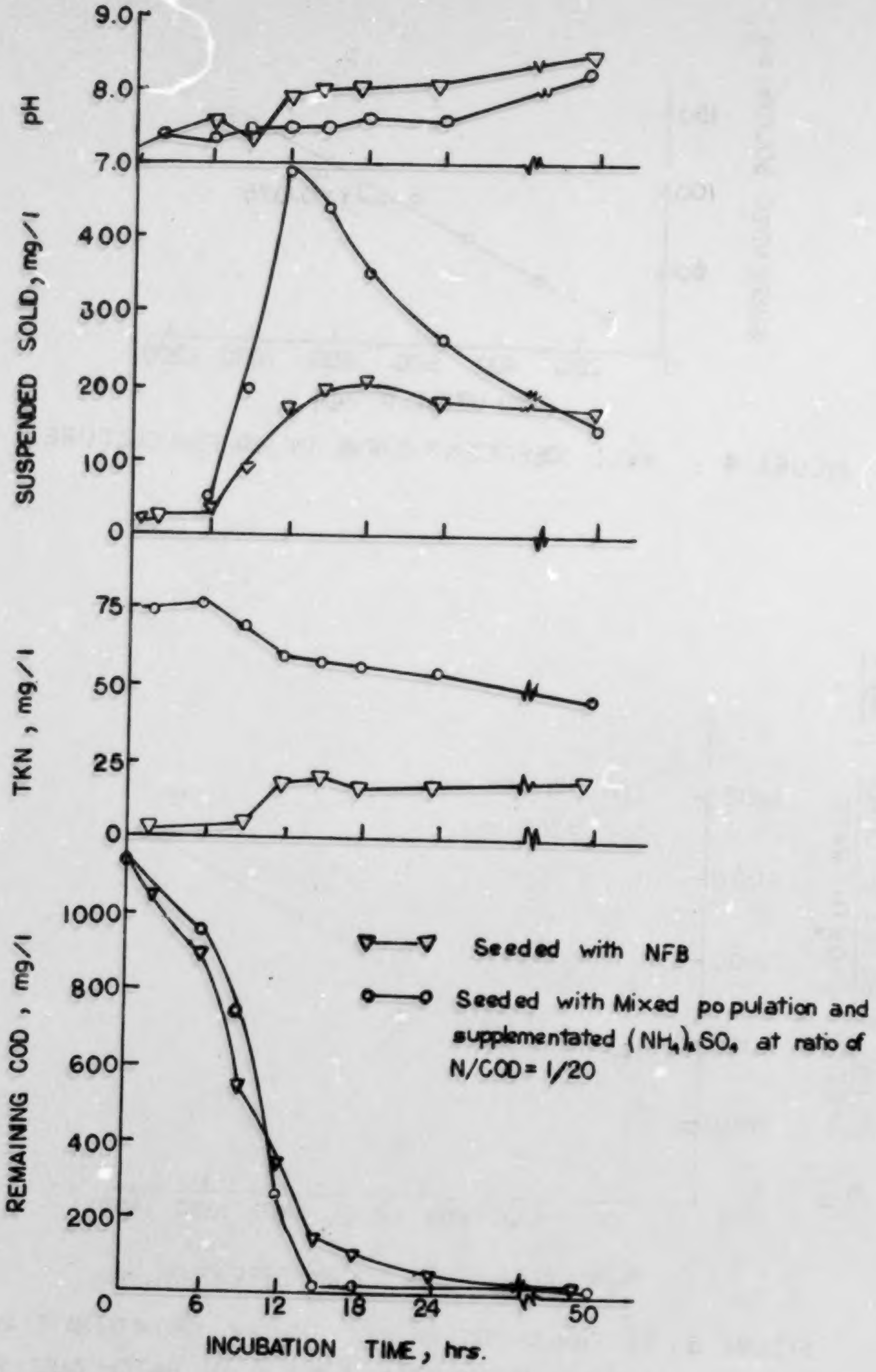


FIGURE 3, COMPARISON OF NFB AND MP CULTURES

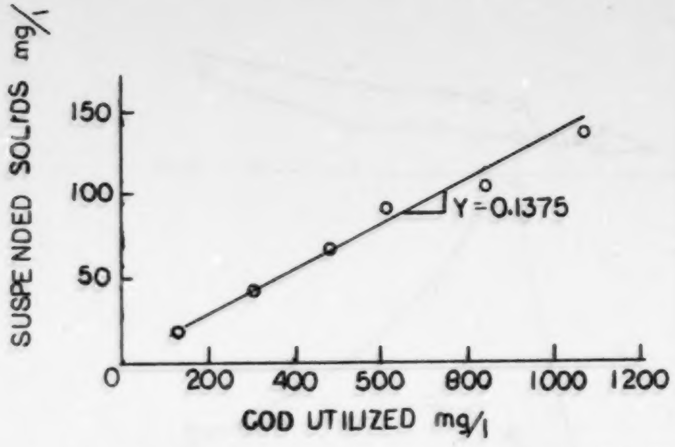


FIGURE 4 , YIELD COEFFICIENT CURVE IN BATCH CULTURE

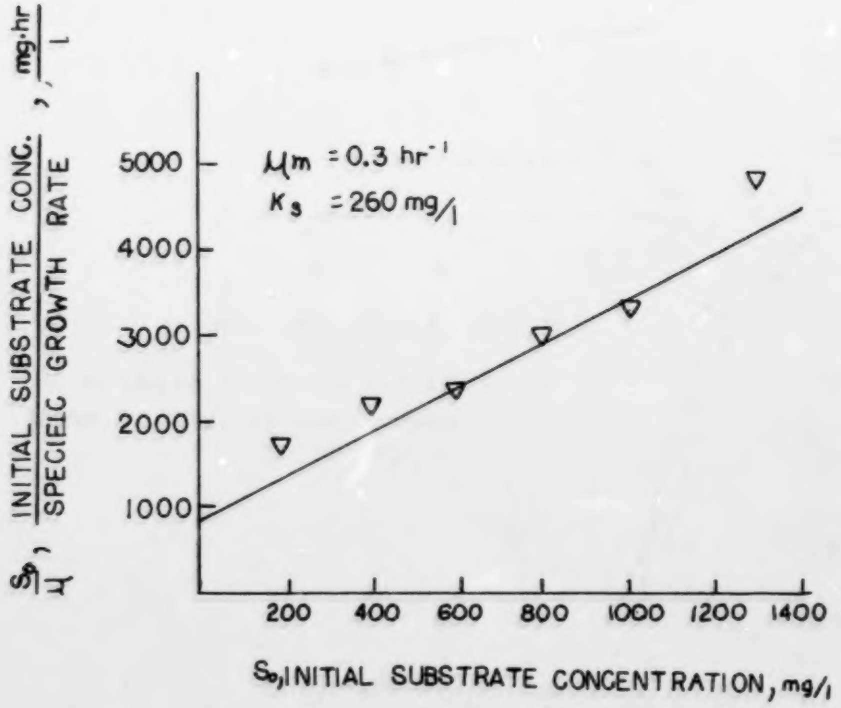


FIGURE 5, DETERMINATION OF MAX. SPECIFIC GROWTH RATE μm AND SATURATION CONSTANT K IN BATCH CULTURE

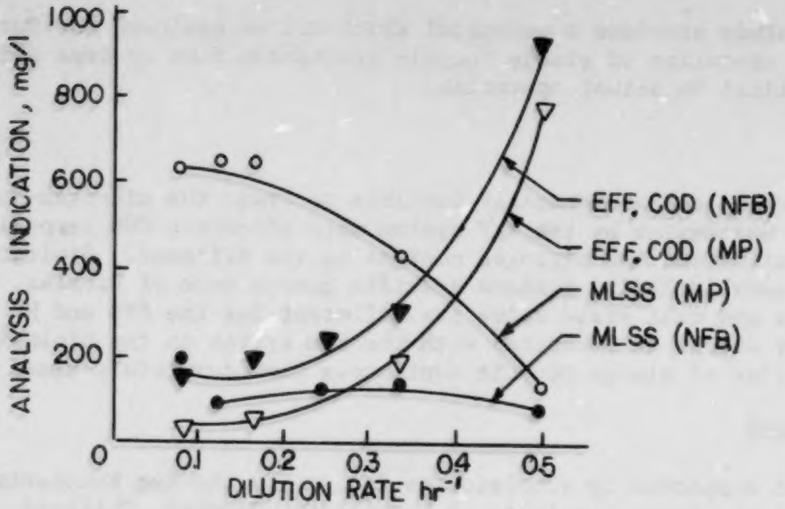


FIGURE 6, DILUTION CURVE FOR NFB AND MP SYSTEMS.

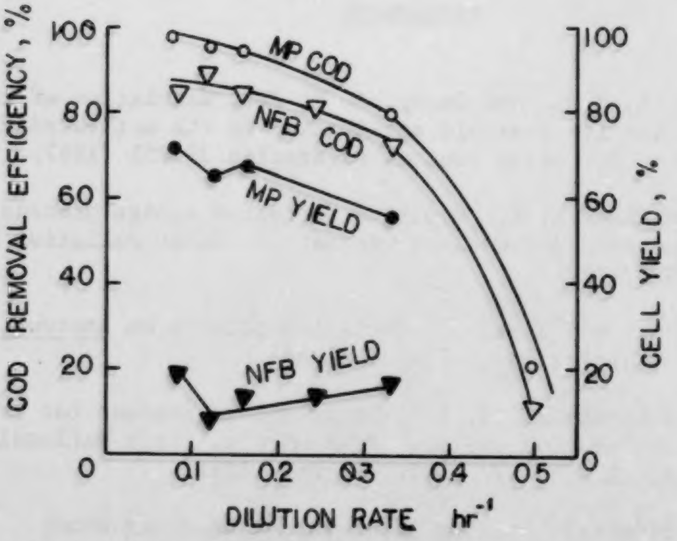


FIGURE 7 EFFECT OF DILUTION RATE ON COD REMOVAL AND YIELD VALUE

biomass as the MP system does. According to the present study, it is shown that the NFB system can be operated as the MP system except for nitrogen addition.

The present study provides a potential which can be explored for further study on the operation of sludge recycle continuous flow systems which can be more practical in actual operation.

SUMMARY

It is technically and economically feasible to treat the nitrogen-deficient carbohydrate wastewater by the NFB system with effective COD removal, low sludge production and low nitrogen content in the effluent. Biological design constants including maximum specific growth rate of biomass, saturation constant and cell yield value are different for the NFB and MP systems. Further study should be conducted with the NFB system on the biological kinetic behavior of sludge recycle continuous flow completely-mixed system.

ACKNOWLEDGEMENT

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TREATING TROUT PROCESSING WASTEWATER - A SUCCESSFUL CASE HISTORY

by

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INTRODUCTION

The Thousand Springs Trout Farms, a subsidiary of Inmont Corporation, is a producer of fresh and frozen rainbow trout for the restaurant market. It is located in the beautiful Snake River Canyon, outside Buhl, Idaho. In this paper, the wastewater problems of Thousand Springs trout processing plant will be discussed, and the efforts made to clean up the wastewater will be reviewed.

Historically, the wastewater from Thousand Springs' processing plant was never considered a pollution problem. First of all, the amount of wastewater involved - around 70 gallons per minute - was insignificant when compared to the water discharged by the adjacent trout farm - some 45,000 gallons per minute. And second, the contaminants in the wastewater were considered as generally good for the receiving waters - an opinion supported by the large population and record size of trout in Clear Lake, the receiving water for Thousand Springs. Consequently, the only wastewater treatment done was coarse screening. However, in order to comply with the strict limits of Thousand Springs' NPDES permit, it was clear that a major clean-up program would be necessary. A two stage program was planned; first, reducing the amount of pollution coming from the plant by improving water use practices; and second, installing an effective end-of-pipe treatment system.

IN-PLANT CLEAN-UP

The first step of any water pollution control project is to define the problem. This was done by carefully inspecting the processing plant, identifying specific wastewater source operations, and conducting a sampling program. To insure the validity of data obtained, great care was taken when conducting the initial wastewater sampling, and all subsequent sampling; composite samples, encompassing all production activities, were taken for several days. Where possible, the results were correlated with historical data.

Upon evaluation, it was found that four operations were responsible for virtually all of the processing plant wastewater.

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These operations were: evisceration of the trout by automatic "gutting machines"; manual rinsing and cleaning of eviscerated trout at "rinse tanks"; manual boning of the cleaned fish at long "boning tables"; and washing down of the processing equipment and work areas at breaks and the end of shifts. Wastewater from this last operation was commonly called "floorwater", after the worker's custom of allowing wash water hoses to run continuously on the plant floor. Other operations at the plant – chilling, inspection, weighing, packing and freezing – were found to involve little or no wastewater.

The results from the initial sampling program are given in Table I. In general, the plant effluent was found to be quite foul. It had a color varying from light to dark pink, a high degree of turbidity, a definite fishy odor, and a somewhat greasy feel.

As can be seen from the table, the gutting machines were by far the most significant source of pollution in the plant, contributing about 36% of the total flow and over 90% of the contamination. This result was not surprising; it is at the eviscerating machines that the fish are first opened up, and the "pollutants" - blood, body fluids, and solids - first allowed to mix with water. Compared to the gutting operation, rinsing and boning were not significant sources of contamination, although the boning tables did contribute an unexpectedly high portion of the total wastewater flow. No practical way was found to sample floorwater. However, based on appearance, the floorwater did not appear to get worse than the average plant effluent, and was usually much cleaner.

The next step in the clean-up program was to determine how the water use practices at each source could be improved. Since it was already clear due to the strictness of the NPDES permit that end-of-pipe treatment would be necessary, methods for reducing both the degree of contamination and the quantity of wastewater were investigated, so that the treatment system would be as small as possible.

By inspection, it was clear that the "floorwater" could be easily reduced. There was no apparent reason why wash hoses had to be left on at all times, so plant personnel were instructed to turn off the hoses when not in use.

After considerable review with the plant supervisors, it was decided that water use at the boning tables could be eliminated almost entirely. Basically, the boning water was used only as a means for conveying bones away from the worker's stations. To eliminate this water conveying system, plastic buckets were placed next to each worker's station. The bones are now directed into buckets by chutes, and are carried away by a designated employee. While more labor is involved, a very considerable

TABLE I - INITIAL WASTEWATER CONDITIONS

Parameter	Plant Effluent	Gutting Machines	Rinsing Tanks	Boning Tables
Flow (gpm)	67.3	24.4	11.9	23.8
BOD_5 (mg/l)	502	1820	190	115
TSS (mg/l)	295	3186	94	22
Oil & Grease (mg/l)	690	1722	168	4

Note: Floorwater could not be isolated for sampling

TABLE II - RESULTS OF CLEAN-UP PROGRAM

Parameter	Effluent Before Clean-up	Effluent After Modifications	Effluent After Treatment	Reductions After Modifications	Reductions After Treatment
Avg. Flow (gpm)	67.3	29.3	25.3	62.4%	62.4%
Max. Flow (gpm)	75	30	30	60%	60%
BOD_5 (lb/1000 lb Fish)	19.8	14.0	2.3	29.3%	88.4%
TSS (lb/1000 lb Fish)	11.6	6.6	1.2	43.1%	89.7%
Oil & Grease (lb/1000 lb Fish)	27.2	2.3	0.4	91.5%	98.5%

reduction of wastewater was achieved, and surprisingly, the boning area is a bit cleaner (the water conveying system was prone to frequent plugging).

At the rinse tanks, the trout are checked to see if the gutting machines have cleaned out all the viscera. The fish are rinsed and any remaining viscera is manually removed. Only a slight reduction in water use was achieved at this source. However, a fair amount of contamination was prevented by having the removed viscera placed into a trough leading to a bucket, rather than thrown into the rinse tanks.

Because the gutting machines were the major water pollution source in the processing plant, more effort was spent on cleaning up them than the other sources. By reducing water flow rates at the various sprays and nozzles in the machines, water consumption was cut about in half. However, this did not significantly affect the amount of contamination. To reduce contamination, a scheme for removing viscera from the wastewater right at the machines was tried. This idea was based on information in the literature indicating that the longer fish viscera is allowed to remain immersed in water, the more contaminants leach out into the water (1). To test the idea, a makeshift separation system was installed. Test samples showed very promising results -- a 33% reduction in BOD and a 59% reduction in oil and grease. With the importance of the leaching phenomenon confirmed, attempts were made to install a permanent separation system right at the gutting machines. While such a system was eventually completed, it proved to be rather cumbersome, labor intensive, and prone to breakdowns.

Fortunately, while the viscera separation system was being worked on, the management at Thousand Springs was also investigating more modern gutting machines -- machines that employed a vacuum for removal of viscera, rather than mechanical removal and water disposal. The new machines were being considered primarily for production reasons, but the managers were confident that they would help with the wastewater problem. The machines were purchased and installed in the summer of 1977, and have proved to be significantly less polluting than the old machines. This is because with vacuum removal, the viscera and much of the blood is sucked away and does not mix with any water. Water consumption by the new machines is also less than by the old machines.

Some mention should be made about the method of disposing of the fish viscera, bones, etc. from the processing plant. The wastes are picked up daily and hauled away as animal feed for mink -- who apparently love it. When significant changes in the waste handling methods were made, the effects of these changes on the mink farmers was considered. Generally, the owners of the mink farms were accommodating to Thousand Springs' needs.

In some ways they even came out ahead as a result of the changes.

After all the water use changes and modifications in the processing plant were completed, samples of the plant effluent were again taken. Table II gives the results of these tests, along with the initial test results, and the results of tests done after installation of the treatment system. As Table II shows, the in-plant changes resulted in considerable reductions in wastewater flow rates and in overall contamination. In view of these reductions, the first stage of the clean-up program was judged to be successful.

It should be noted that the results concerning BOD, TSS, and oil and grease are given in terms of pounds of contaminant per thousand pounds of fish processed. Since production at the processing plant has more than doubled since the wastewater clean-up program began — to a current production peak of over 30,000 lbs/day--such a production-based measure is necessary to allow meaningful comparisons.

TREATMENT SYSTEM INSTALLATION

After the various changes in the processing plant were in place (except for the new gutting machines, which weren't installed until later), an investigation was made into what type of treatment system to install. Performance criteria for a treatment system were based on what was needed to achieve compliance with the final limits of Thousand Springs' NPDES permit.

When evaluating wastewater treatment strategies, the problem of space was very important. The Thousand Springs Trout Farm is very short on space, and any large treatment system would have cut into productive fish impoundments. The only readily available space was a little-used building at the outfall end of the trout farm, measuring about 16 feet wide, 30 feet long, and 9 to 14 feet high.

Several treatment strategies were investigated, including lagooning, extended aeration, activated sludge treatment, chemical treatment and air flotation. Lagoons and extended aeration systems were ruled out because of space requirements. Chemical treatment was eliminated because of generally low treatement efficiencies and lack of data relating to fish processing wastewater. Activated sludge systems were found to be feasible; however, such systems still required somewhat more space than was readily available. Also, they would cost more than twice as much as air flotation systems, and would have trouble with the high oil and grease loadings.

The literature indicated that air flotation systems, with chemical additions, could treat fish processing wastewater as effectively as conventional biological treatment systems, and yet take up very little space (1) (2). A number of flotation system manufacturers were contacted and invited to submit proposals based on the performance criteria. Both dissolved-air and dispersed-air flotation systems were considered. The system selected was a dispersed-air flotation system with chemical addition and fine screening, proposed by SWECO, Inc.. SWECO was selected primarily because they appeared to have the most experience with fish processing wastes and because they could guarantee the greatest BOD removals.

Wastewater treatment in the SWECO system is done primarily by three pieces of equipment — a coarse belt screen, a centrifugal screen concentrator (CSC), and a sludge flotation tank. The belt screen consists of a series of polyethylene panels with 1/4-inch openings. The CSC is essentially a rapidly rotating drum with screens on the outside, through which the wastewater is pumped from the inside. It uses 165-mesh stainless steel screens. The flotation tank measures 4 feet wide, 12 feet long, and 4½ feet deep, and is equipped with a foam skimmer.

Other components of the SWECO system are a 300-gallon surge tank, a non-clog wastewater pump, a vibrating separator with 165-mesh screens, three chemical feed tanks and pumps, an automatic screen washing system, a 1500-gallon sludge holding tank, and an integrated control panel. The system operation is described below.

Wastewater from the processing plant flows by gravity to the SWECO room. Once there, it falls through the coarse belt screen into the surge tank. Large pieces of fish viscera are removed by the belt screen, and are dumped into a chute leading to the sludge holding tank. The surge tank serves to level out peaks in the wastewater flow rate. Alum is added to the wastewater at the surge tank.

From the surge tank, the wastewater is pumped to the centrifugal screen concentrator, with lime being injected into the stream right after the pump. The CSC serves two functions: it removes fine solids, and it aerates the wastewater. Solids removed by the CSC flow out the bottom of the unit to the vibrating separation screen, which dewaters them. The dewatered solids are discharged to a drum, while the water is recirculated back to the surge tank. Just prior to leaving the CSC unit, an anionic polymer is injected into the wastewater stream.

The wastewater then flows by gravity to the bottom of the flotation tank. There, the fine floc formed due to the alum and lime addition is coalesced by the polymer and floated to the top of the flotation tank by entrained air. A moving skimmer pushes the floating, foamy sludge over a collection weir into a trough, from which it flows to the sludge holding tank. After skimming, the fully treated wastewater is discharged over another weir. Sludge and solids collected in the holding tank are periodically pumped out and hauled away to a landfill.

The entire treatment system is controlled from one control panel, and can be operated either manually or automatically. Periodically, the system cycles into a cleaning mode. In this mode, the fine screens of the CSC unit and vibrating separator are backwashed by a high pressure spray of hot water mixed with detergent.

With regard to space, the SWECO treatment system fits quite comfortably into the 16-by-30 foot room available, with ample room left over for a workbench and storage shelves. The sludge holding tank is located underground outside the room.

As with most complex installations, the start-up of the SWECO treatment system had a few problems. In particular, problems were encountered with the wastewater pump due to stringy solids, and with the coarse screening operation (not part of SWECO's package). But for the most part, these problems have now been overcome. Initial chemical concentrations were as suggested by Barnett and Nelson in their studies - 220 mg/l of alum, 150 mg/l of lime and 5 mg/l of polymer (2).

The results of tests to determine the efficiency of the SWECO system are shown in Table III below:

TABLE III - PERFORMANCE OF SWECO SYSTEM

Parameter	Raw Wastewater	Treated Wastewater	Treatment Efficiency
BOD_5 (mg/l)	1180	189	84%
TSS (mg/l)	562	100	82%
Oil and Grease (mg/l)	189	28	85%

The tests show that the system is quite efficient in treating the wastewater. It should be noted that when the tests were made, no effort had yet been made to optimize removals by adjusting chemical feed rates, cleaning frequency, etc. After some experience, removal efficiencies are expected to be even better.

CONCLUSIONS

Referring again to Table II, it can be seen that, overall, the wastewater clean-up program at the Thousand Springs Trout Farm was very successful. Reductions of BOD and suspended solids were close to 90%, and the reduction of oil and grease was a remarkable 98.5%. As experience is gained with the SWECO treatment system, better reductions may be achieved.

Considering the reductions obtained, it is felt that the cost of the clean-up program was very reasonable. Installed cost of the SWECO treatment system was about $60,000 (1977 dollars), while the cost of the entire clean-up program was about $80,000. These cost figures include all testing and engineering, but do not include the cost of the new gutting machines, which were installed primarily for production reasons. The cost figures also do not include the labor of Thousand Springs Trout Farm personnel, who contributed nearly all of the labor involved in the project.

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ACKNOWLEDGMENT

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RECIRCULATION OF CONTAINER COOLING WATER AS A MEANS OF WATER CONSERVATION IN FOOD PROCESSING PLANTS

by

Nabeel L. Jacob*

INTRODUCTION

Water is the most common medium used for cooling thermally processed containers of food. Cooling is accomplished in a variety of systems such as the use of still retorts as coolers, cooling canals, agitating spin coolers, rotary pressure or atmospheric coolers, spray coolers or water application in the cooling leg of a hydrostat (3). In general, cooling water is either used once and discharged or reused for cooling, or other purposes.

Container cooling is one of the most water consumptive operations in any food processing plant. Depending on the type of product packed and the water use practices, cooling water requirements represent between 25 to 85 percent of the total volume of water used daily in the plant (1 , 3). Acquisition of such a large volume of water is no longer free even for the processors who rely exclusively on wells for their fresh water supply. Disposal of wastewater, whether to a municipal treatment plant or to a company operated treatment facility, has also become a significant cost item in food processing. Therefore, maximizing the use of such a copious volume of good quality cooling water, through recirculation or reuse, can be an effective means of implementing a successful, overall water conservation program through which substantial savings can be realized (3).

NFPA SURVEY OF CONTAINER COOLING SYSTEMS

Recognizing the significance of the microbiological, chemical and physical characteristics of cooling water as major factors determining the feasibility and extent of its reuse, a survey was conducted by NFPA (formerly NCA) to specifically determine these characteristics in a number of container cooling systems.

Over the two-year period of the project, a total of sixty-five (65) visits were made to seventeen (17) California canneries where 210 cooling water samples were collected for laboratory testing. The study covered seven (7) different cooling systems, eight (8) major commodities and twelve (12) specialty products.

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In general, samples were collected in various ways depending upon the type of cooling system surveyed. At the time of sampling, the concentration of total residual halogen (chlorine or iodine) in the water was determined and the temperature and pH were recorded. Residual chlorine or iodine in water samples collected for microbiological testing was immediately neutralized by adding sterile 1% sodium thiosulfate solution. Samples were then refrigerated, for no longer than 40 hours, until examined. All laboratory tests were performed in accordance with the Standard Methods for the Examination of Water and Wastewater (5).

RESULTS AND DISCUSSION

The physical and chemical characteristics of the samples collected are summarized in Table I. The total hardness (as $CaCO_3$) showed the highest degree of dispersion as determined by the standard deviation value. The least variability was that of the pH of the water. The TOC/COD ratio had a range of 0.10-4.41 with an arithmetic mean of 0.63 and SD of 0.69. Halogen concentration will be considered in a later part of the discussion.

TABLE I. SUMMARY OF CHEMICAL AND PHYSICAL CHARACTERISTICS

Characteristic	Range	Mean	S. D.
COD, ppm	0.0 - 281.0	26.9	37.8
TOC, ppm	0.0 - 77.0	12.8	11.5
TSS, ppm	0.0 - 98.0	4.4	6.3
Hardness ($CaCO_3$), ppm	10.0 - 500.0	92.7	87.8
Grease & Oil, ppm	0.0 - 23.0	4.0	4.2
Temperature, ^0C	9.4 - 66.7	28.1	19.5
pH	6.0 - 9.6	8.1	0.53

Microbiologically, the aerobic Total Plate Count (TPC), aerobic and anaerobic Mesophilic Spore (MSC), Staphylococci and Coliform Counts were determined in the cooling water samples. Table II gives a summary of these characteristics.

TABLE II. SUMMARY OF MICROBIOLOGICAL CHARACTERISTICS

Characteristic	Count/ml (Range)
Total Plate Count (TPC)	<1 - 205,000*
Mesophilic Spore Count (MSC)	
a. Aerobic	<1 - 20
b. Anaerobic	<1 - 4
Staphylococci	<1 - 13
Coliforms	<1 - 950*

*No detectable germicide residue.

An examination of the percentage distribution of bacterial counts in the samples (Table III) indicates that 64% of the water samples had TPC in the range of <1 - 100/ml. Of these samples, 40% showed negative results (<1/ml). The MSC was generally low. There were no detectable aerobic sporeformers in about 80% of the samples, and the maximum count did not exceed 20/ml. Anaerobic sporeformers were only recovered from 4% of the samples and at low density levels (highest count was 4/ml). Staphylococci counts of between 1 and 10/ml were present in only 3% of the samples. Densities of more than 10/ml (with a maximum of 13/ml) were encountered in 1% of the water samples. Toxin tests were negative in all samples that showed positive Staph results. Coliforms were detected in about 12% of the samples.

TABLE III. PERCENTAGE DISTRIBUTION OF BACTERIAL COUNTS IN COOLING WATER

		MSC			
Count/ml	TPC	Aerob.	Anaerob.	Staph.	Coliforms
<1	25.6	79.5	96.4	96.4	88.2
1 - 10	19.5	17.9	3.6	2.7	0.9
11 - 100	19.0	2.6	-	0.9	1.8
101 - 1,000	16.4	-	-	-	9.1
1,001 - 10,000	9.7	-	-	-	-
10,001 - 100,000	6.7	-	-	-	-
>100,000	3.1	-	-	-	-

Occurrences of aerobic sporeformers in relation to different ranges of TPC had no definite trend. The anaerobes, on the other hand, showed a steady increase with the TPC in ranges higher than 100/ml.

The frequency of coliform and staphylococci detection increased as the general bacterial population increased to maximum levels. However, no linear trend was apparent.

MAXIMIZING THE USE OF CONTAINER COOLING WATER

Because of the recent drought conditions that affected the western and midwestern states, food processors should make every effort to maximize the use of container cooling water. This can be basically accomplished through reuse. The results obtained and observations made in our study indicate that the voluminous discharge (Table IV) from container coolers is, in most cases, more than suitable for reuse, with minimal treatment, in lieu of fresh water.

TABLE IV. VOLUME OF WATER DISCHARGED FROM VARIOUS TYPES OF COOLERS

Type	Range
Still Retorts	1300 - 4000 Gal./Cooling Cycle
Spray Coolers	6300 - 20,000 Gal./Hr.
Spin Coolers	3700 - 6300 Gal./Hr.
Cont. Coolers	2400 - 6000 Gal./Hr.

The reuse of cooling water can be implemented in two ways with the option of employing both, or either one exclusively (Fig. I):

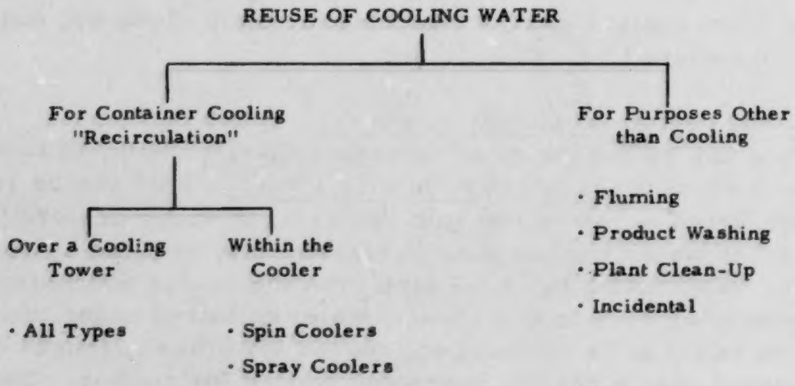

Fig. I. Water conservation through reuse of cooling water.

1. The reuse for purposes other than container cooling:
The discharge from cooling systems can be reused without further treatment for fluming and product washing (1, 3, 4) thus eliminating a number of points of fresh wateruse. This practice is known as the counter-flow reuse pattern which can be adapted in various ways in most food processing plants. Water conservation acquired through this practice is depicted in Fig. II which illustrates three unit operations common in all food processing plants.

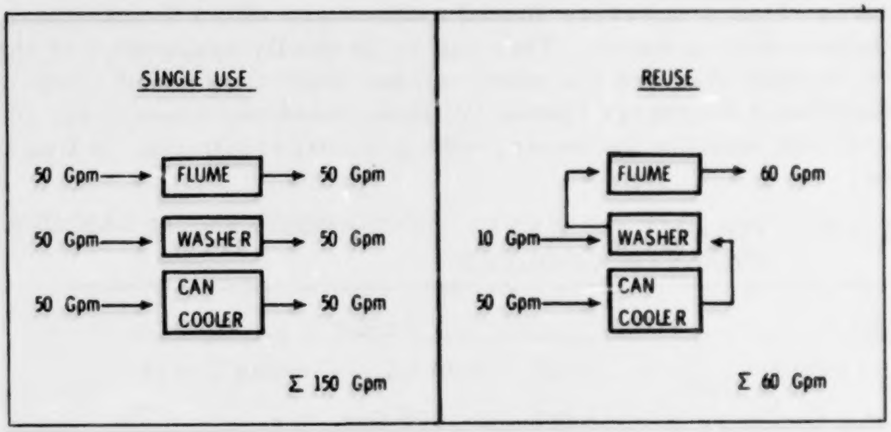

Fig. II. Counter-Flow reuse of cooling water.

Discharge from coolers can be used also for plant clean-up, belt lubrication and boilers (1).

2. The reuse for container cooling purposes:
This method can be implemented through either, or both, of two ways:
   (a) Recirculation of the water within the cooler. This can be readily accomplished in spray and spin coolers. In spray coolers (Fig. III), fresh water consumption is significantly reduced by collecting the water under the final section of the cooler and reuse it in the preceding section and so on. Water collected under the initial section can then be discharged, reused for other purposes or recirculated over a cooling tower and reused for cooling. The same concept applies to spin coolers as illustrated in Fig IV.

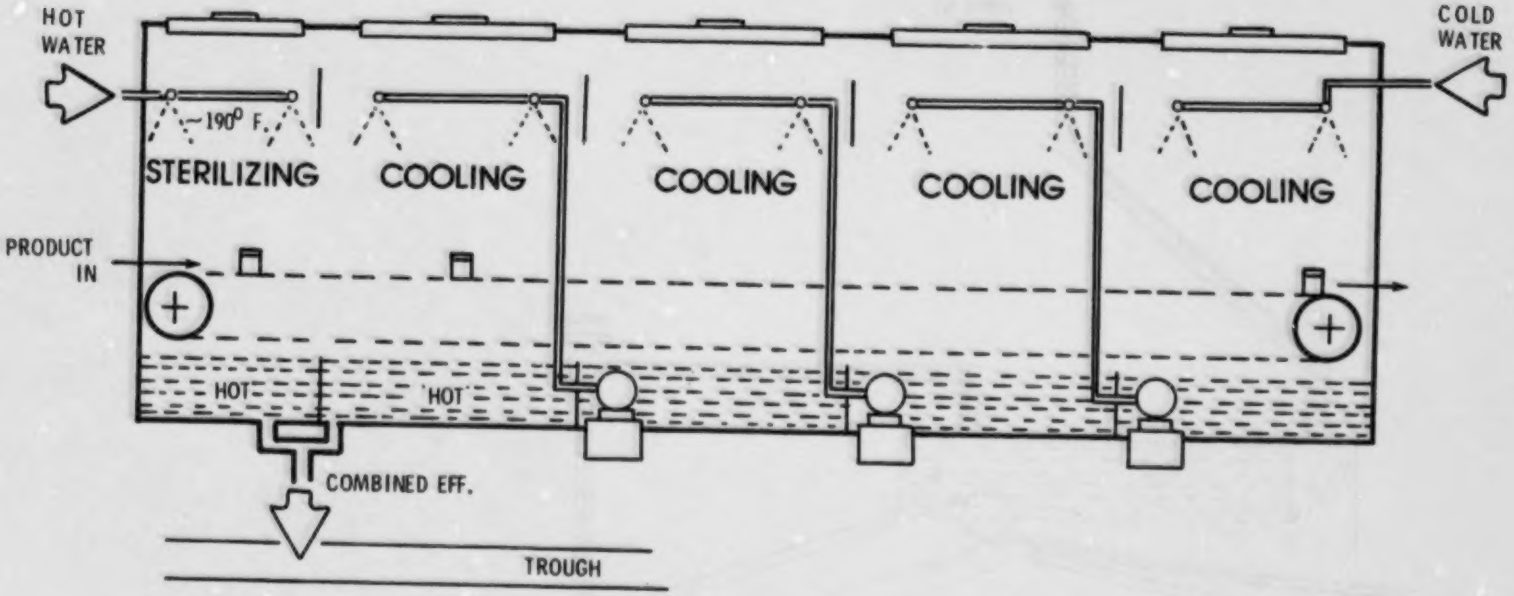

Fig. III. Water recirculation within the cooler "spray cooler."

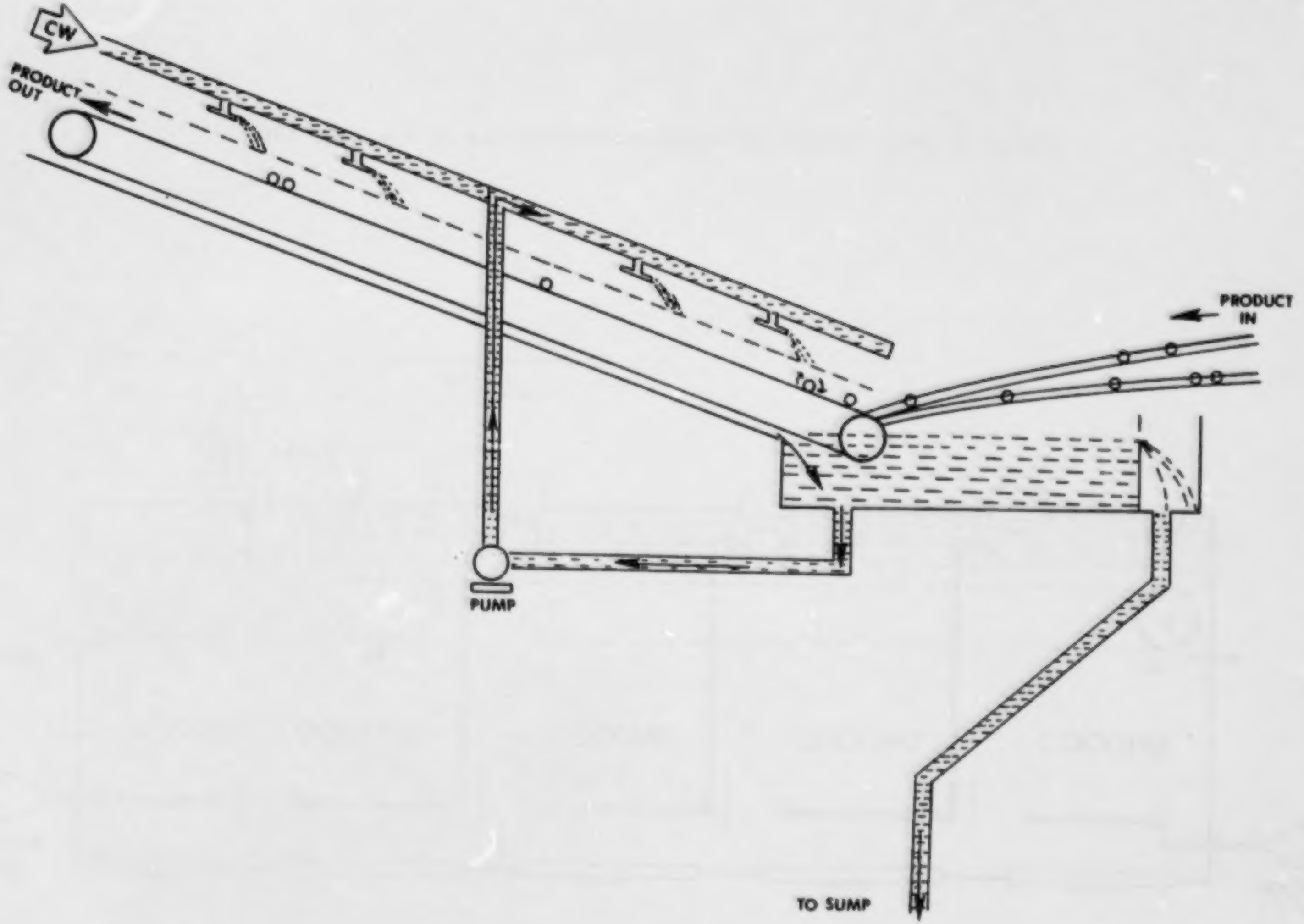

Fig. IV. Water recirculation within the cooler-"spin cooler."

(b) Recirculation of the discharge from coolers over a cooling tower and reuse for container cooling. This practice, as illustrated in Fig. V, may require some revision of the existing hydraulic flow in the plant. However, reductions of as high as 80% of the daily cooling water consumption have been reported by plants now using cooling tower systems.

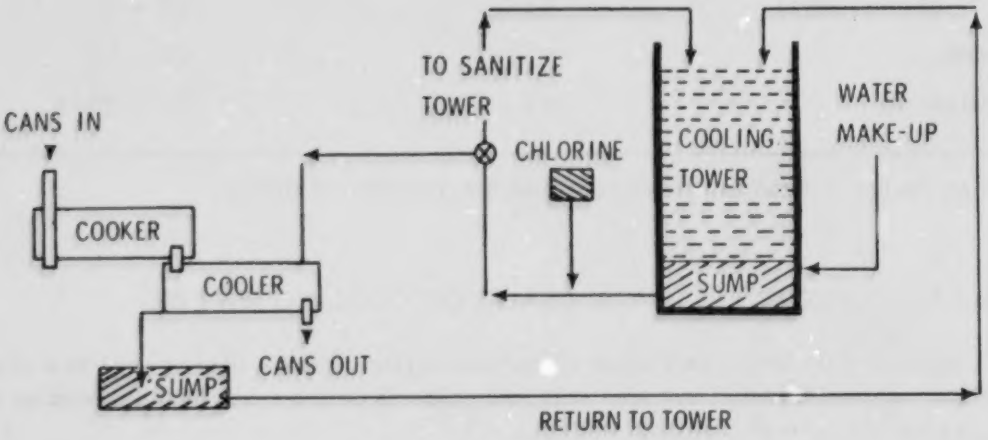

Fig. V. Schematic of a cooling tower system.

It should be emphasized at this point that water used in recirculated systems is particularly prone to bacterial and organic matter build-up as shown by the survey data. Table V shows the effect of recirculation on various characteristics of cooling water. The build-up trend is apparent. Therefore, the operation of recirculated cooling water systems requires special attention to avoid adverse conditions.

TABLE V. THE EFFECT OF RECIRCULATION ON THE CHARACTERISTICS OF COOLING WATER

Characteristic	Single - Pass (28% of Samples)	Recirculated (72% of Samples)
COD, ppm	0.0 - 133.0	0.0 - 281.0
TOC, ppm	0.6 - 48.5	1.1 - 77.0
pH	7.6 - 9.6	6.0 - 9.2
Residual, Cl_2, ppm	0.0 - 9.5	0.0 - >10.0
Bacterial Counts/ml:		
TPC	<1 - 1680	<1 - 205,000*
MSC (Aerobic)	<1 - 2	<1 - 20
" (Anaerobic)	<1	<1 - 4
Staph.	<1 - 1	<1 - 13
Coliforms	<1	<1 - 950*

*Cooling water contained no detectable germicide residue.

MEANS TO ACHIEVE MAXIMUM USAGE OF COOLING WATER

Based upon the findings and upon the observations made throughout the study, the following considerations are offered collectively as necessary means of maximizing the use of cooling water:

1. Adequate Knowledge of the System:
   This is the first requirement in any water conservation program. Serious problems may result from the lack of knowledge of what I call "the system plumbing." Misapplication of chlorine, in recirculated water systems, is an example. Therefore, you should survey the system and maintain an updated floor plan or a schematic diagram with all water lines, points of chlorine application, sumps -- etc., indicated thereon. An example of such a map is shown in Figure VI. This map is specifically useful in trouble-shooting.

2. Disinfection:
   Disinfection is probably the most effective means for achieving maximum usage of cooling water. Our study has shown that the presence and level of a germicide residual in the cooling water determine to

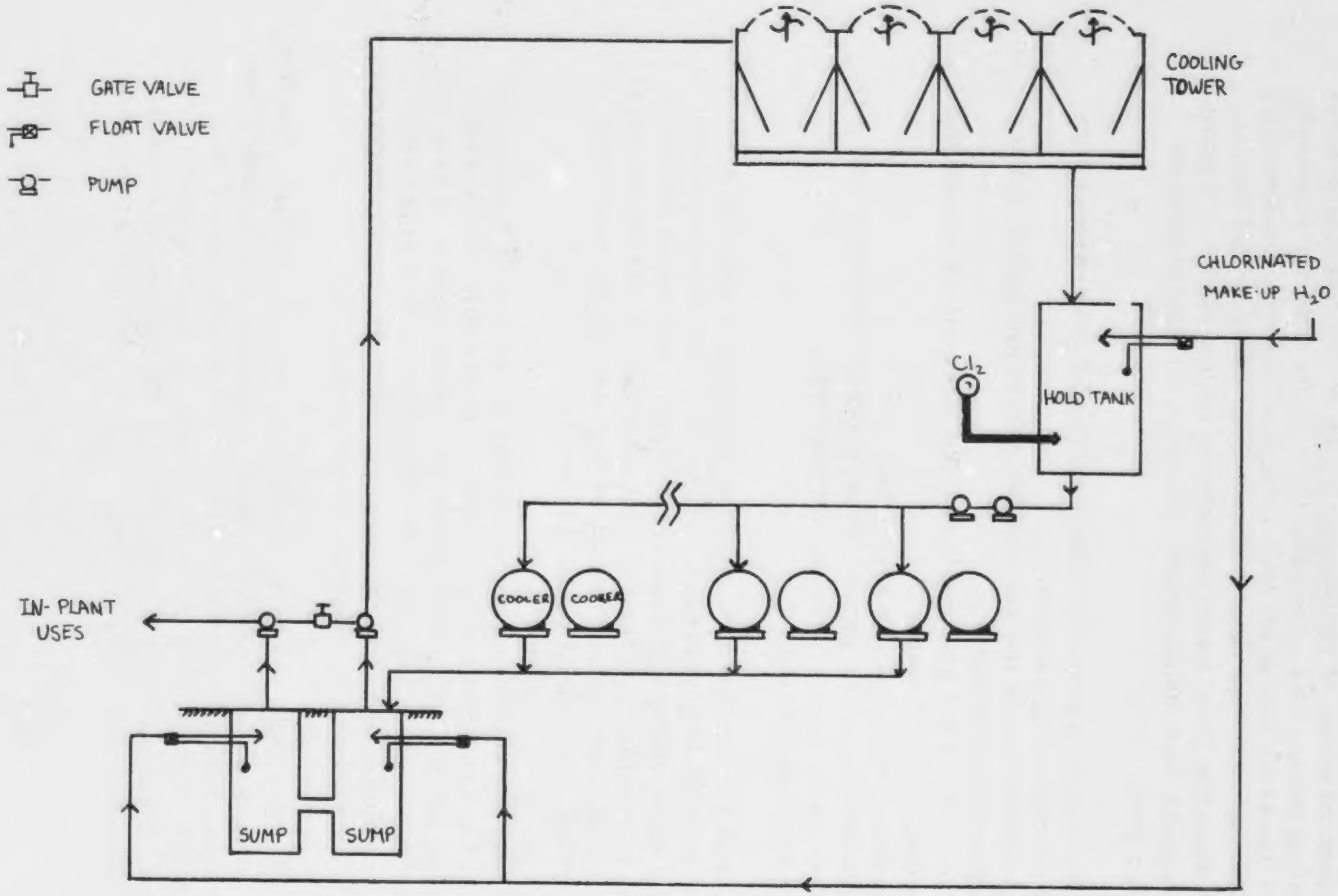GATE VALVE
FLOAT VALVE
PUMP
COOLING TOWER
CHLORINATED MAKE-UP H2O
Cl2
HOLD TANK
COOLER
COOLER
IN-PLANT USES
SUMP
SUMP

Fig. VI.

a large extent the microbiological quality of the water which in turn determines the feasibility of its reuse. Table VI shows the definite effect of the concentration of residual chlorine on the microbiological quality of cooling water. As expected, the results indicate a general trend towards lower counts of all four groups of microorganisms with increasing residual chlorine level. In general, all bacterial counts were highest when the level was undetectable or low (0.0 - 1.0 ppm). No bacterial growth was encountered, however, at concentrations higher than 3,1 ppm.

Selection of the proper germicide should be based upon careful consideration of the following aspects:

(a) Thorough evaluation of the germicidal efficacy acquired under typical operational conditions.
(b) The corrosivity of the germicide and the effect of its use on the characteristics of the water.
(c) The regulatory status of the germicide.
(d) The compatability of the germicide with other chemicals added to the cooling water (e.g., oxygen scavengers).
(e) The cost and added benefits.

For several well known reasons, gaseous chlorine is still the preferred choice of most food processors. However, chlorination of container cooling water definitely requires adequate control of the residual chlorine levels in the water. Inadequate control results in either corrosion of containers and equipment or high bacterial counts and the absence of sanitary conditions in the water.

It is evident that the stability and germicidal efficiency of a given concentration of chlorine are greatly influenced by the pH, temperature, total suspended solids (TSS) and organic load of the water. Therefore, the characteristics of cooling water will determine, to a large extent, the required minimum level of chlorine. By considering the hardness of the water, corrosivity can also be predicted (3).

To achieve adequate control of the established level of residual chlorine, the plant must have an individual assigned to monitor and maintain records of residual chlorine concentrations in the cooling water on a continuous basis. Monitoring program should include both water feeding, and water discharged from, the cooler. Monitoring of residual chlorine in the latter assures the adequacy of chlorine dosage applied to the first.

TABLE VI. THE EFFECT OF RESIDUAL CHLORINE CONCENTRATION ON BACTERIAL COUNTS* IN CONTAINER COOLING WATER

Resid. Cl_2 Range, ppm	% of Samples	TPC	MSC		Staph.	Coliforms
			Aerobic	Anaerobic		
0.0 - 1.0	52.9	<1 - 205,000	<1 - 23	<1 - 4	<1 - 13	<1 - 1000
1.1 - 2.0	14.4	<1 - 69,000	<1 - 16	<1 - 2	<1	<1 - 500
2.1 - 3.0	12.3	<1 - 6,500	<1 - 20	<1	<1	<1 - 10
3.1 - 4.0	5.4	<1 - 200	<1 - 5	<1	<1	<1
4.1 - 10.0	13.4	<1 - 75	<1 - 2	<1	<1	<1
>10.0	1.6	<1	<1	<1	<1	<1

*Per milliliter

Monitoring and control can be done either manually or automatically. Orthotolidine comparators, or alternate methods such as the use of "Water-Chex" for chlorine, are normally used at the cannery to determine chlorine concentration in the water. Chlorine dosage is then manually adjusted on the basis of that reading.

Automatic monitoring and control systems, currently available, consist of four major components; an analyzer, a recorder, a controller and an automatic valve on the chlorinator to adjust chlorine dosage. These automatic chlorine monitor/controllers are particularly useful in recirculated cooling water systems.

Iodophors (surfactant-iodine complex) have been in use for several years as sanitizing agents. However, the practical experience with these compounds for the specific application of disinfecting container cooling water is extremely limited. Our study of the very few cooling systems using iodophors has revealed some shortcomings. An example is the adverse effect on the characteristics of the water exerted by the phosphoric acid, and organic surfactant contents of the iodophor. The first caused the pH range to drop to 2.9 - 4.8 in the cooling water, and the latter increased the COD range from 0.0 - 281.0 ppm to 470.0 - 969.0 ppm. Therefore, an in-depth study of the effectiveness of these compounds, under typical production conditions, is necessary before any conclusions can be drawn.

Chlorine Dioxide should not be considered as a direct replacement for chlorine in all cases (7). The advantage of ClO_2 is that it offers better germicidal efficiency in situations where chlorine is adversely affected by conditions that exist in the water to be treated. Persistently high content of organic matter, especially phenolic and nitrogenous compounds, and excessively high pH are mainly the adverse conditions that affect chlorine. These conditions are not normally encountered in container cooling systems. Application of ClO_2 also involves some cost and safety consideration.

3. Regulations:

For the low-acid food processors, the GMP regulations (CFR 21: 113.60) advises that cooling water be chlorinated as necessary so that there is a measurable free chlorine residual, or its equivalent of other safe chemicals, in the water at the discharge end of the cooler. This regulation is currently under revision by FDA and is expected to be mandatory.

In single-pass systems, a concentration of at least 0.5 ppm of residual chlorine, measuredatthe discharge point, is adequate (2 , 6).

Recirculation of cooling water normally requires higher concentrations due to the potential build-up of organic and inorganic matter, and of the bacterial population. The layout of the system, the type of coolers and the characteristics of the water used therein determine the required level of residual chlorine. The results of our study show that a range of 2.0 - 4.0 ppm is normally adequate. When these ranges of residual chlorine are constantly maintained in the cooling water, bacterial population is not expected to exceed 100 colonies/ml in most cases. At this recommended max level of contamination (3 , 6), occurrence of leaker spoilage is very unlikely and bacteria of public health concern are seldom encountered.

Section 110.80 of the GMP is another regulation that determines the purpose for which cooling water could be reused (4). It states that ". . . water shall not be reused for washing, rinsing or conveying food products in a manner that may result in contamination of food products." This means that cooling water containing chemicals such as rust inhibitors and others, should not be reused for purposes other than container cooling regardless of its good microbiological quality (6).

4. Awareness of Potential Problems Pertinent to Certain Types of Coolers:

Water samples collected from systems in which containers are cooled exclusively in Still Retorts were of excellent bacteriological quality. High TPC was encountered only when there was no detectable residual germicide in the water. Container cooling in a still retort is a batch-type operation. Therefore, the cooler is quite accessible for inspection and cleaning, and build-up of food residues inside the cooler is easily avoidable.

The operation of Continuous Pressure Coolers is different. Circumstances may allow food residue from the exterior of filled, processed cans to wash off and accumulate in the cooling water. Occasional mechanical jams which cause containers to burst within the cooler, pose a major source of organic contamination of the cooling water. Over-lubrication of the moving parts of the cooler is another source of such a contamination. The presence of organic matter in high concentrations not only provides nutrients for bacterial growth in the cooling system, but also reduces the germicidal effectiveness of the disinfectant, present in the water, through chemical reactions. Reaction with chlorine residues, for instance, is a good example. Furthermore, build-up of suspended solids, whether organic or inorganic (especially in recirculated water systems), affords bacteria a type of physical protection against the action of the germicide present in the water. Growth of certain types of bacteria is also enhanced in these systems by the relatively high temperatures (120-140°F) especially in inadequately disinfected water.

When these conditions exist, leaker spoilage, especially of largest and smallest can sizes, is frequently encountered. Therefore, it is essential that continuous pressure coolers be drained, cleaned and sanitized on a regular basis. Of equal importance is that an adequate level of residual chlorine, or its equivalent, be maintained in the cooling water in order to assure tight control of microbial growth in the system.

In Hydrostatic Retorts, cooling water is normally recirculated within the system (Fig. VII). After cooling, water returns to a basin located either inside or outside the structure of the hydrostat. Cooling water is then pumped to the spray nozzles inside the hydrostat's cooling leg. The water in the basin is particularly prone to accumulation of grease and oil, and build-up of bacterial population. This situation requires the continuous removal of the accumulated organic matter and the maintenance of an adequate level of residual chlorine in the water.

Surfaces within the cooling leg of the hydrostat should be inspected on a regular basis. If heavy contamination is evident, surfaces should be immediately cleaned and sanitized. Maintenance of an adequate chlorine residual in the discharge may require direct injection of chlorine into the basin. Chlorine requirements of the system must be determined through a monitoring program in which microbiological and other characteristics of the water are considered.

In various types of Spray Coolers, there is the potential for the accumulation of organic matter and microorganisms on the various surfaces within the cooler, (e.g., belt conveyors - pans, etc.). Breakage of glass containers, inefficient cleaning operations and inadequate chlorination of the water are some of the most common causes of the problem. When spray coolers are operated in the single-pass pattern, the problem is more of an aesthetic nature. But if cooling water is being recirculated, the quality of the water used to cool the containers will be significantly affected by the conditions that exist inside the cooler. Again, inspect, clean, sanitize and properly disinfect the cooling water.

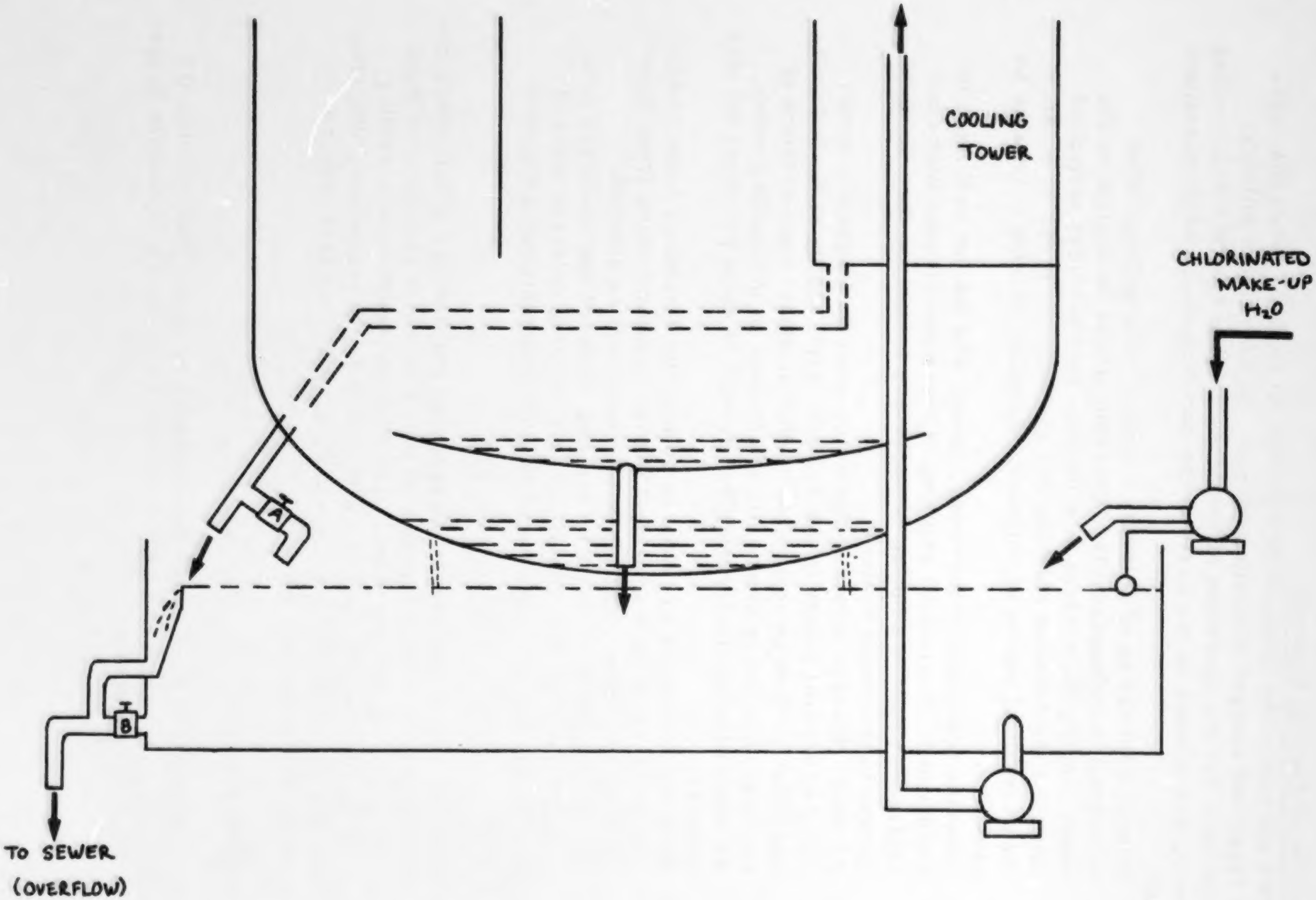

Fig. VII. Cooling water system of a hydrostat.

5. The Use of Cooling Towers:

It was not within the scope of this project to study in detail the various types and designs of cooling towers. However, the following guidelines, for the operation of container cooling systems with cooling towers, are offered on the basis of the data acquired and observations made.

(a) Proper application of chlorine (or other safe and approved chemical) is indespensable. Chlorine should be applied to the water feeding the coolers at a location that provides sufficient contact time between chlorine and the water in order to enhance the germicidal action of chlorine. Adequate mixing must also be provided.

(b) Chlorine provision to the tower, itself, and the hot well must be maintained. Periodical slugging of these components with concentrated chlorine solution is necessary to control the microbial growth in the whole system.

(c) Residual chlorine levels in the water must be frequently monitored at several points in the system, particularly at the hot well, and chlorine dosage controlled so that adequate concentration of residual chlorine is constantly maintained in the cooling water. An automatic monitor/controller system is quite practical for this purpose.

(d) When floor troughs are used to collect the discharge from coolers and transport it to the hot well (sump), contamination from floor washing and other clean-up operations must be avoided.

(e) Finally, the system must be drained, cleaned and sanitized on a regular basis so that conditions of excessive chlorine demand can be avoided and sources of microbial contamination eliminated.

In conclusion, I'd like to emphasize the fact that the findings of this study reinforce NFPA's previous recommendation that a constant chlorine residual, or its equivalent, is necessary to maintain sanitary conditions in cooling water, particularly when the water is recirculated. Nevertheless, chlorination does not substitute for manual cleaning, proper container closure or careful post-cooling container handling.

ACKNOWLEDGEMENT

The author gratefully acknowledges the cooperation of the food processors who participated in this study and the laboratory assistance of Marcia Seeger and Chris Merlo of the NFPA.

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LOW BOD RECIRCULATION STEAM BLANCHING

by

D. R. MacGregor* and P. Parchomchuk**

INTRODUCTION

The blanching operation is the largest single contributor to wastewater BOD in a typical vegetable processing operation. Several workers have modified conventional steam blanching methods to reduce BOD output by various means. Water blanching, although widely used, does not seem to possess the same possibilities for BOD reduction.

Among low BOD steam blanching systems which have been developed is the hot gas blanching system of Ralls et al. (1) which achieves very great reductions in BOD while maintaining organoleptic quality and nutritive value. Operating costs are generally higher than hot water or steam blanching. A hot gas blanching process has been patented (2) in which steam is added to the burning gas to prevent moisture loss from the product. Forced circulation of the combustion gas-steam mixture gives a fluidized bed effect.

Another system which significantly reduces BOD production in the blanching/cooling process is the modified IQB method (3). This method reduces effluent volume by reducing steam usage and by using atomized blancher condensate to replace water in the air cooling section. The combination of IQB blanching with air cooling has reduced COD production 50% and effluent volume 98.6% as compared to a conventional steam blanch with flume cooling. Product quality is good but, even though liquid is added to the cooling air, losses due to drying during cooling are large.

In a study by Lund (4) comparing different blanching methods for seven canned vegetables, an average of 5.7 lb of BOD were produced per ton of material with conventional belt steam blanching compared to 4.4 lb per ton for IQB blanching. IQB blanching was found to be inferior to pipe blanching for corn while for other products the blanching method had no significant effect on product quality.

BACKGROUND

The object of the work being reported here is to remove from the waste water stream all BOD produced in the blanching process in a commercially feasible manner.

Since steam blancher condensate is essentially a dilute juice it seemed that a modification of juice concentration technology could be used to reduce blancher effluent to a compact concentrated form. Concentration of juices by evaporation produces large quantities of steam which could then be used for blanching.

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Juice concentrators normally use boiler steam to provide energy for evaporation and steam generated is used in succeeding evaporator stages. In blanching, where the objective is to produce a maximum amount of steam, a somewhat different approach is required. Also use of boiler steam to generate secondary steam involves additional energy losses and capital costs. For these reasons, it was decided to utilize a direct fired evaporator for generating steam. In our original work several systems in which burning natural gas was brought into direct contact with the blancher effluent were tried. These were not successful because of the large ratio of non-condensible gasses to water vapor and consequent lowering of condensation temperature.

STEAM GENERATOR UNIT DESIGN AND OPERATION

The final design, of which a pilot plant model was built and tested, consists basically of a gas fired vertical tube and shell thermosyphon heat exchanger (Fig. 1). Heat is transferred to the evaporator tubes from the flame tube using oil (Essotherm N-69) as a transfer medium. The flame tube 102 mm in diameter, and is baffled with 25 mm diameter oil filled cross-tubes. The unit is surrounded by an insulated shell containing the heat transfer oil and 17 evaporator tubes 12.7 mm dia. x 1220 mm long. This gives a flame tube surface of 0.78 m^2 and evaporator tube surface of 0.83 m^2. Feed liquid enters through a manifold at the bottom and is carried up the evaporator tube by the steam generated. Excess liquid is recycled and the steam is fed to the blancher where it condenses on the material being blanched and is returned to the steam generator. Provision is made by means of a float valve for addition of make up water as needed. Non-volatile materials leached from the product being blanched are concentrated in the steam generator and bled off when a predetermined concentration is reached. Bleed-off is controlled by a temperature sensor which responds to the increased boiling point due to increased solids. An in line refractometer would be somewhat more sensitive and much more expensive. A flow diagram of the system is shown in Fig. 2.

For testing the unit, sufficient quantities of blancher effluent were collected from commercial steam blanchers and either used immediately or stored refrigerated at 2°C or frozen at -28°C until needed. The test blancher consisted of a 20 cm x 120 cm stainless steel wire mesh belt with a variable speed drive. Steam was delivered by a perforated pipe spreader located between the upper and return section of the belt. The treatment section of the blancher was enclosed in galvanized metal with rubber flaps at inlet and outlet to allow product to pass without excess steam loss. No special provisions, such as insulation, were made to reduce heat loss from the blancher.

The general procedure for test runs was as follows: 1) commercial blancher effluent was fed into the steam generator and the flame was started and regulated to hold the temperature of the heat exchange oil at 190°C. 2) steam from the generator was fed into the blancher and any condensate was returned to the generator. Excess steam was allowed to waste. 3) when solids in the generator had built up to a predetermined level (normally 70% T.S.S. by refractometer)the test vegetable was run through the blancher. Blanching times were selected to give a negative peroxidase test. 4) feed-

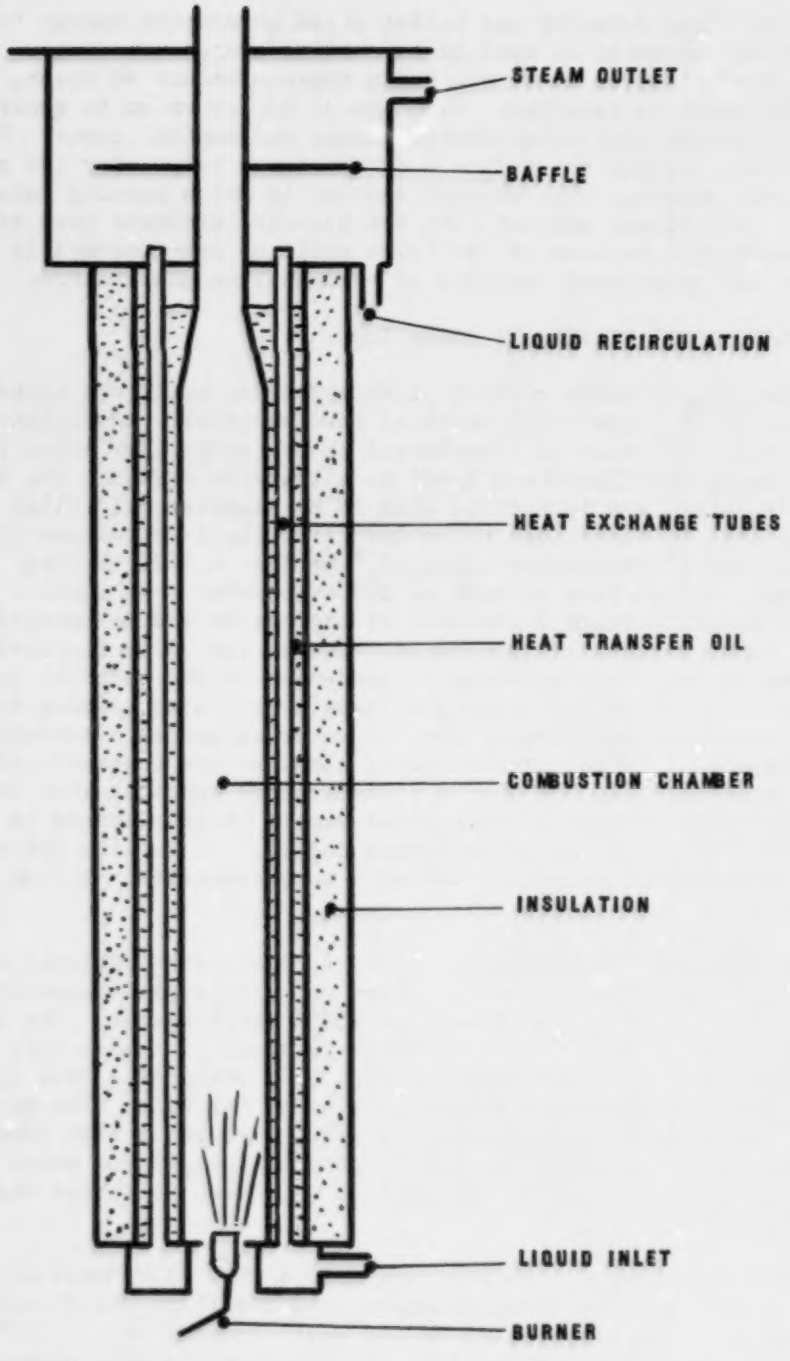

Fig. 1. Gas fired steam generator - concentrator prevents burning of concentrated soluble solids by using intermediate heat transfer oil to maintain low tube surface temperatures.

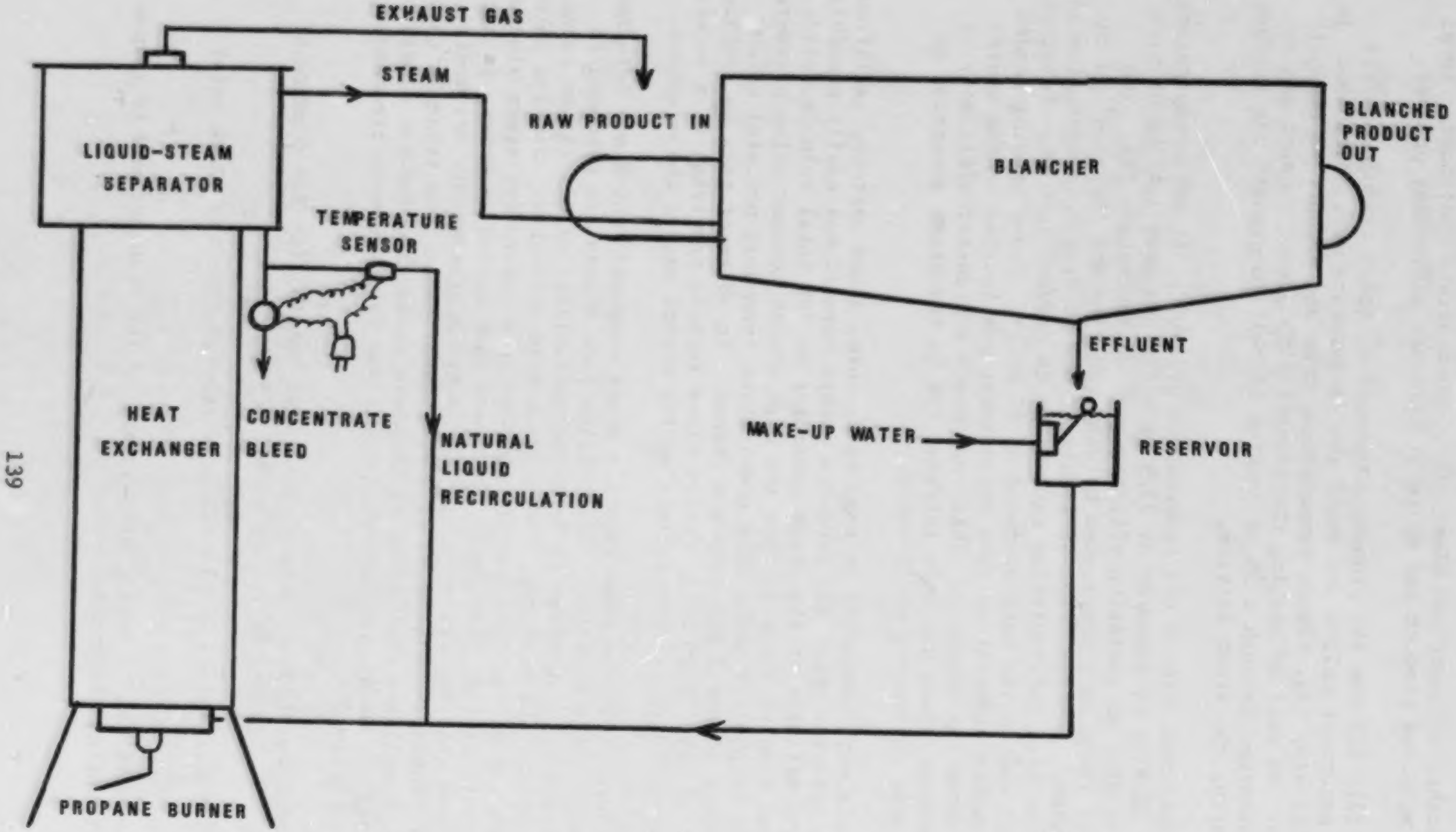

Fig. 2. Heat exchanger vaporizes and recirculates effluent back to blancher while concentrating soluble solids leached from product during blanching.

ing in of blancher effluent and bleed off of concentrate continued. Total running time with one product was up to 37 hr (over a five day period).

During steps (2), (3) and (4) propane consumption, steam production, oil temperature, generator solids and stack gas temperature were monitored. In addition during step (3), blanch temperature, time and product throughput were measured. As well as heating the product with steam, exhaust gas at 150°C was discharged through a 35 cm section of belt to preheat the product prior to entering the steam section.

The unit is operated with an oil temperature of 190°C. At this temperature it generates 19.8 kg of steam/hr or 23.9 kg/m^2/hr and uses 1.45 kg of propane per hr to give an operating efficiency of approximately 71%. The temperature of 190°C is a compromise between capacity and 'burn on' in the evaporator tubes. Recirculation of liquid in the generator is approximately 360 l/hr. This high recirculation rate helps to prevent burn on. Practical blanching rate was in the neighbourhood of 60 kg/hr. Heavy loading tended to reduce blancher temperature (the thermometer was located in the center of the unit above the product). This represents a blancher efficiency of only 39%, however, since our main interest was in the steam generator no attempt was made to improve performance.

Blanching tests were conducted on asparagus, corn, diced carrots, cauliflower and brussels sprouts. With all products except corn it was easily possible to concentrate effluent in the steam generator to 70% total soluble solids. Corn presented some problems in that the high starch concentration prevented concentration beyond 40% and a fine precipitate (probably protein) which tended to adhere to metal surfaces was formed. In spite of this no problem was encountered with 'burn on'. Future plans include provision of a screen to remove precipitates and particulate matter washed out of the blancher.

Blancher effluent contains some volatile aroma compounds which are returned with the steam to the blancher. In addition some aromas are produced in the steam generator. In order to test the possibility of off flavor transfer to the material in the blancher, taste tests were conducted. Samples taken from the same lot of vegetables were blanched in a laboratory steam blancher and in the recirculation blancher, these were then cooled in water, packaged in polyethylene bags and frozen at -28°C. After approximately one month samples were cooked and presented to a ten member panel in a triangle test. In this test panellists were asked to indicate preference for the single or paired sample. No significant difference was found between treatments or in acceptability.

In summary recirculation blanching shows real possibility for commercial application. It has the following advantages:

1. All BOD involved in blanching is removed from the waste water stream.

2. The unit can be installed adjacent to the blancher and is responsive to fluctuating steam demands.

3. Fuel efficiency is increased by elimination of heat losses from boiler flue gases, steam pipes, etc.

4. It is a zero pressure system and does not require a stationary engineer.

5. It is adaptable to present steam blanchers with the only modifications needed being in the steam distribution system.

6. It relieves boiler loading and will allow plant expansion without the need for increased boiler capacity.

7. It reduces water consumption and energy costs associated with delivery of water.

8. The concentrate produced has potential use as an animal feed ingredient.

It is hoped that a prototype capable of producing steam to blanch 1000 kg/hr will be built and field tested for the 1979 season.

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LAND VS ACTIVATED SLUDGE TREATMENT OF POTATO PROCESSING WASTE WATER

by

K. Lynn Sirrine*

INTRODUCTION

A comparison of treatment systems is discussed for the treatment of potato processing waste water. The intent of the paper is to present actual problems associated with the treatment of potato processing wastes using the activated sludge treatment method and the eventual conversion to land treatment of these wastes.

BACKGROUND

The water pollution problem in some areas of Southeastern Idaho became very critical during the winter and spring of 1960-61 at which time approximately a quarter of a million fish were killed in the Milner Reservoir portion of the Snake River. In addition to the fish kill, a septic condition was created in the river and the water quality for domestic use was endangered. The Snake River and its tributaries above the Milner Reservoir constitute a major drainage system in Southeastern Idaho. Located along the banks of the Snake River and its tributaries above the Milner Reservoir are numerous municipalities and industries some of which discharged portions of their waste into these streams. The capacity of this river system to tolerate the waste disposal load placed upon it was reduced due to decreased water in storage and increased use of these waters for irrigation. Because of the waste load and the low water flow in the river, the aforementioned pollution condition did develop and the State Board of Health requested that all contributors try to do something to reduce the waste being discharged to the streams. The potato processors of Idaho in the spring of 1961 immediately organized a committee which largely consisted of technical personnel representing all of the major potato processing companies in the State. This committee later became known as the Engineering Committee of the Potato Processors of Idaho Association.

After making an extensive literature search and running a series of comprehensive laboratory studies, the Engineering Committee decided to verify their laboratory findings in a full scale pilot plant waste treatment facility in October of 1962. This study was operated until March of 1963.

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Since potato processing was a relatively new industry, very little information was available concerning the treatability of potato waste material. As a result, the industry encountered many different taxing problems which required an all out effort to solve. This initial pilot plant study, which was conducted at the R. T. French Company in Shelley, Idaho, was routinely reviewed and visited by engineers and technical people from all over the United States who were seeking information concerning our research work. The Engineering Committee won the coveted "Air and Water Protection Award" for 1963 by the presentation of a summary report on this study to the Water Pollution Control Federation at a meeting in Seattle, Washington.

The Potato Processors of Idaho spent about $35,000 to $40,000 in time and material on this primary treatment study which was completed in six months. By November of 1963, all 15 potato processing plants located in the critical area of the Snake River had installed primary treatment plants. The installation of these plants decreased the potato processing pollution load to the Snake River by about one half and cost the potato processing industry in Idaho about 3 to 3.5 million dollars. In other words, the potato processing industry quickly responded as responsible citizens of Idaho to meet the State Board of Health's request for all contributors of pollution to reduce their pollution load to the River. After completion of the primary treatment studies, work immediately began on secondary waste treatment. The activated sludge treatment technique appeared to give the highest degree of treatment on the potato processing waste waters.

ACTIVATED SLUDGE

In 1968, a secondary waste treatment system was constructed under a federal grant, being reported on in report number 12060EHV at the R. T. French Company in Shelley, Idaho, 12/70, to treat potato processing waste waters.(1) About 50 to 60% of the waste water requiring treatment came from the potato peeling operation.

Design factors for the activated sludge treatment system included two aeration basins. Aeration Basin 1 holds 1.25 million gallons and normally contains three 50-hp floating mechanical aerators. Aeration Basin 2 holds 2.5 million gallons and normally utilizes six 50-hp floating mechanical aerators. Both basins have a water depth of 16 feet. The design BOD loading is 28 lb/1,000 cu ft/day when the two aeration basins are operated in parallel. The aeration basins are constructed of earth and were lined with PVC (polyvinyl chloride). The bottom of the basins were sloped to prevent forming pockets for entrapment of water or gas. A sun-resistent Hypalon plastic sheet was placed around the perimeter of the basins to protect the PVC from exposure to sunlight.

The secondary clarifier is 70 feet in diameter and has a 12-foot side water depth. The clarifier has a rapid sludge withdrawal mechanism. The hydraulic overflow rate is 325 gal/sq ft/day at the design flow of 1.25 mgd.

SECONDARY TREATMENT FACILITY DESIGN FACTORS

INFLUENT PUMPS

Number	2
Type	Centrifugal
Capacity	
Each	1,300 gpm
Total	2,600 gpm
Total Head	27 feet
Constant Speed	870 rpm

SLUDGE RECIRCULATION PUMPS

Number	2
Type	Centrifugal
Capacity	
Each	435 gpm
Total	870 gpm
Total Head	18 feet
Constant Speed	870 rpm

WASTE SLUDGE PUMP

Number	1
Type	Positive displacement
Capacity	100 gpm
Total Head	46 feet
Speed	550 rpm
Drive	Variable - speed

AERATION BASINS

Number	2
Type	Earthen
Volume of Basin 1	1.25 million gallons
Volume of Basin 2	2.5 million gallons
Basin Water Depths	16 feet
Basin Side Slopes	2:1
Basin Freeboard	2 feet
Basin Lining	PVC with Hypalon cover in sun-exposed area
Number of Aerators, Basin 1	3
Number of Aerators, Basin 2	6
Design Organic loading	28 lb BOD/1,000 cu ft/d

AERATION EQUIPMENT

Number Aerators in Aeration Basins	9
Type	Floating pump type mechanical surface aerators with variable oxygen transfer-power draw feature
Oxygen Transfer Capacity	75 pounds per hour each in aeration basins with mixed liquor suspended solids = 4,000 mg/l, operating elevation = 4,627 ft. above MSL, temperature at 20 degrees C., Alpha = 0.85, Beta = 0.90, and operating dissolved oxygen = 1.5 mg/l

SECONDARY CLARIFIER

Number	1
Diameter	70 feet
Side Water Depth	12 feet
Mechanism Type	Multiple port hydraulic suction
Design Flow	1.25 million gallons/day
Overflow Rate at Design Flow	325 gal/sq ft/day
Detention Time at Design Flow	7.2 hours

The plant was a modern plant utilizing mechanical floating aerators, but did not have sludge wasting equipment. The plant was loaded at an average load of 14,100 lbs of BOD/day. D.O. levels of around 1 mg/l were easily maintained. Even though the influent pH was rather high (9.5 to 10.5) the pH buffered easily without the addition of chemicals. The process water temperature ran about 21° C (70° F) and was cooled to about 7.2° C (45° F) through operation of the aerators. Numerous mechanical problems were encountered and we soon realized that considerable maintenance attention was needed to keep the equipment operational.

The major problem encountered with the activated sludge treatment system was in the clarification of the mixed liquor suspended solids. Low D.O. operation seemed to produce filamentous organisms that further hindered the clarification process. As designed, the facility would not meet the effluent requirements for discharge to the Snake River due to suspended solids and BOD concentrations, although if the solids were removed, the BOD would also be in exceptable limits. Even with these problems, this plant won an award for design and for development of operating parameters for activated sludge treatment of potato processing wastes.

With the research study finished and the necessity for operation of the facility with an effluent of good quality on a day to day basis, it became evident that this system would require additional expenditures to improve clarification of the mixed liquor. Also, proper sludge handling equipment had to be added. We felt that changes and additions to the facility would cost about $350,000 and after spending this much we would still be faced with:

1. More stringent effluent controls in the future.
2. The possibility that clarification of the effluent could not be accomplished at a reasonable cost.
3. Even with sludge handling equipment, we would have a residue to dispose of.
4. Increased operating costs due to energy and labor.
5. Even more additions in the future.

LAND TREATMENT

An evaluation of various modifications to the activated sludge treatment system was made. During these evaluations, it became more apparent that perhaps other treatment techniques should be looked into. One system,(2) land treatment, was receiving some success in the state. After an evaluation of this technique, we found that we would be able to purchase land, and install a land treatment system for less expense than modifications to the present facility. In addition to the reduced capital expenditures, we also found that the operating costs would be less and that a crop of grass hay could be taken from the land treatment system which would further reduce our operating costs. Added to these benefits, we would eliminate our waste water discharge to the Snake River.

Our Shelley land treatment facility consists of 164 acres of land divided into 22 sub fields of about 7.5 acres. The land has been leveled and graded to a specific grade, diked and seeded with a mixture of grasses. The water is distributed over the land by a network of sub surface and surface pipes. A peeler modification was made in the processing plant to reduce the sodium concentration in the waste water. Waste water characteristics are:

1. COD 3,000 to 4,000 mg/l
2. BOD/COD ratio 0.83
3. pH 6.5 to 7.5
4. Temp. 18°C (65°F)
5. Total nitrogen 100 mg/l (as N)
6. Ammoniacal nitrogen 10 to 15 mg/l (as N)
7. Nitrates 1 to 2 mg/l (as N)
8. Iron 2 to 3 mg/l
9. PO_4 5 to 7 mg/l (as P)
10. Flow 1.15 MGD

Operation of the system is quite simple, as one sub field is watered for 24 hours. The fields are watered in rotation taking about 22 days for a cycle, dependent upon weekend operation. Organically, we are loading the land at about 175 lbs of COD/acre/day. Nitrogen is about 5.8 lbs of N/acre/day. We operate for about 230 days for a total organic load of 40,250 lbs/year and a nitrogen load of about 1,334 lbs/year. We harvest about 4 tons/acre of hay that runs about 13% protein. However,(3) most of the nitrogen is removed through denitrification in the soil. COD removal is excellent, about 96% is removed after percolation through 6 feet of soil.

Cost Comparisons

Cost	Activated Sludge	Land Treatment
1. Labor, operation	$14,200	$4,600
2. Labor, farm management	--	22,000
3. Power	25,000	700
4. Maintenance		
Labor	8,000	4,500
Parts	6,000	1,000
5. Solids Disposal	Not constructed	
6. Laboratory supplies	7,000	5,000
7. Operating supplies	4,000	500
Sub total	64,200	38,300
Income	--	23,000
Total	64,200	15,300

No cost data is available for the disposal of waste activated sludge from the activated sludge plant. The estimated total investment for the activated sludge system without the demonstration project was $431,379 in 1968. This estimate does not include sludge wasting facilities. Sludge wasting was estimated at $350,000, so the total plant costs would have been around $780,000 in 1968.

The land treatment system cost $350,000, which included the cost of the land. Peeler changes in the processing plant cost $160,000 for a total investment of $510,000 (1973). The peeler changes also reduced the organic load by about 30% and increased the amount of product being sold as cattle feed from the primary waste plant. This increase only amounted to about $6,000/year, which would not justify the peeler change without the waste treatment need.

OPERATING PROBLEMS

The activated sludge system was a high maintenance plant. The more the equipment added and operated, the higher the maintenance costs. The floating aerator motors being the # 1 maintenance problem. Problems are also encountered with too high a suspended solids concentration in the clarifier effluent. The suspended solids separation being the # 1 operating problem. Under good conditions an exceptable effluent could be achieved. However, seldom was the effluent quality good enough to meet the discharge permit requirements. At times, odors from the facility were offensive to nearby residents.

These problems can be overcome either through equipment additions or modifications or through operation, chemical additions and etc.

Land treatment systems have to be designed for the hydraulic and organic load placed on them. The water distribution system used affects design with respect to field grading, etc. Assuming that the system has been designed for waste treatment and is not merely a disposal area, problems can still develop.

A poorly designed system will have problems with odors, insects, ponding, poor percolation, poor water distribution, killing of grass, etc. A well designed system may have problems with odors and water percolation and build up during the winter operation in cold climates. The design of the facility is more important than one might think. The odor problem being the major problem, especially during the spring thaw period of say March and April. Odors can be suppressed by chemical additions, pipe line aeration and some changes in rotation of field used. Good grass cover helps as does a green buffer of tall shrubs and trees around the fields. Winter operating problems can be eliminated through proper design considerations.

SUMMARY

An evaluation of our objectives concerning waste treatment revealed that the activated sludge treatment facility was not giving us the service that we wanted. It almost seemed at times that we were no longer a potato processor, but a waste treatment facility.

By taking a fresh look at the situation and by obtaining the views of two outside consultants*, we were convinced that we were going in the wrong direction.

Since regulatory agents and agencies are not defined for all time, regulations change. A waste treatment facility must be designed with enough flexibility that it doesn't become a burden on the owner and that he is not continually burdened with expensive modifications, additions and operation.

Land treatment of our potato processing waste water has given us the flexibility and simplicity that we need. Some problems still exist but are reasonable. Hopefully, the benefits of this type treatment system to the food processor are seen by the regulatory people and there use considered and not placed in jeopardy by new unnecessary regulations.

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Dr. W. Wesley Eckenfelder, Jr., Vanderbuilt University, Nashville, Tenn.

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Soil Scientists, Agricultural Engineer and Biological Technician
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A DESIGN PROCEDURE FOR LAND APPLICATION

by

E.J. Kroeker*, A. Lamb*, and J.M. Haskill**

INTRODUCTION

Land application of wastewater began long before the development of today's complex treatment plant techology. Use of effluent for a beneficial purpose was reported in Germany in the sixteenth century and from that beginning the application of sewage effluents to farmland was practiced in continental Europe and England.

Land application approaches have a great deal of potential for alleviating the wastewater management problems facing the food processing industry. The problems become especially acute for those plants located in relatively small communities whose municipal sewage treatment plants are not able to handle the highly concentrated wastewaters usually produced by food processing plants. Where land is readily available at reasonable cost, land application provides an attractive alternative to wastewater treatment and disposal.

In addition to providing a means of wastewater renovation and removal, land application provides a means of recycling nutrients and water through cover crop irrigation and groundwater recharge. Land application disposal of wastewater is also usually less energy intensive than today's mechanical treatment processes.

Figure 1 summarizes the important steps in the selection, design and implementation of land application systems for wastewater treatment. This paper will discuss various types of land application systems currently used for treatment of various food processing wastewaters, mechanisms of wastewater treatment in these systems and the importance of each of the major design variables; it will conclude with a brief description of a design methodology which should be followed in the selection and design of such systems.

METHOD OF LAND APPLICATION

Most land application systems used in the food-processing industry employ one of the following surface application methods illustrated in Figure 2:

1. irrigation
2. overland flow
3. infiltration filtration

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** Program Engineer, Water Pollution Control Directorate, Fisheries and Environment Canada, Ottawa, Ontario

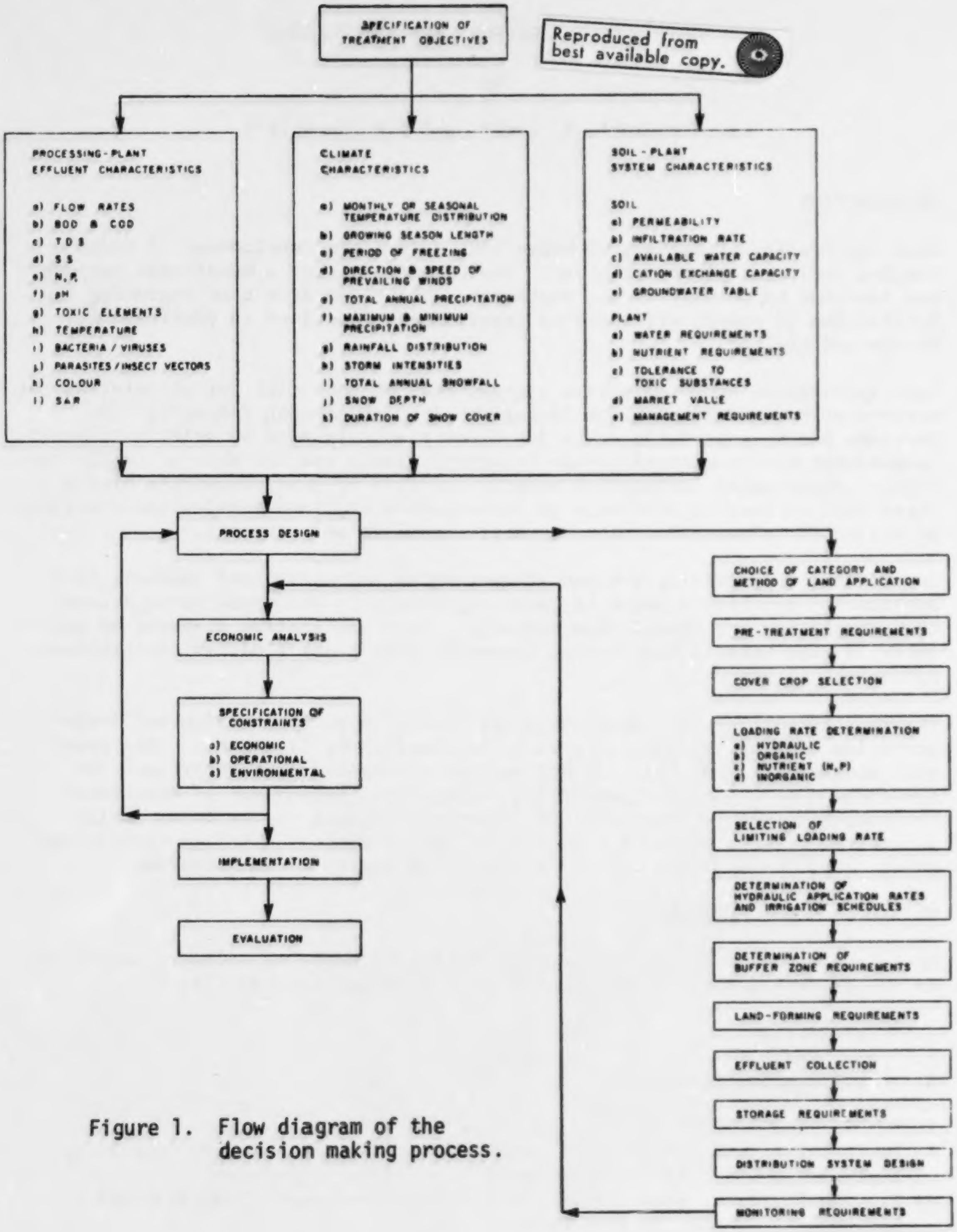
SPECIFICATION OF TREATMENT OBJECTIVES
PROCESSING - PLANT EFFLUENT CHARACTERISTICS
a) FLOW RATES
b) BOD & COD
c) T D S
d) S S
e) N, P,
f) pH
g) TOXIC ELEMENTS
h) TEMPERATURE
i) BACTERIA / VIRUSES
j) PARASITES / INSECT VECTORS
k) COLOUR
l) SAR
CLIMATE CHARACTERISTICS
a) MONTHLY OR SEASONAL TEMPERATURE DISTRIBUTION
b) GROWING SEASON LENGTH
c) PERIOD OF FREEZING
d) DIRECTION & SPEED OF PREVAILING WINDS
e) TOTAL ANNUAL PRECIPITATION
f) MAXIMUM & MINIMUM PRECIPITATION
g) RAINFALL DISTRIBUTION
h) STORM INTENSITIES
i) TOTAL ANNUAL SNOWFALL
j) SNOW DEPTH
k) DURATION OF SNOW COVER
SOIL - PLANT SYSTEM CHARACTERISTICS
SOIL
a) PERMEABILITY
b) INFILTRATION RATE
c) AVAILABLE WATER CAPACITY
d) CATION EXCHANGE CAPACITY
e) GROUNDWATER TABLE
PLANT
a) WATER REQUIREMENTS
b) NUTRIENT REQUIREMENTS
c) TOLERANCE TO TOXIC SUBSTANCES
d) MARKET VALLE
e) MANAGEMENT REQUIREMENTS
PROCESS DESIGN
ECONOMIC ANALYSIS
SPECIFICATION OF CONSTRAINTS
a) ECONOMIC
b) OPERATIONAL
c) ENVIRONMENTAL
IMPLEMENTATION
EVALUATION
CHOICE OF CATEGORY AND METHOD OF LAND APPLICATION
PRE-TREATMENT REQUIREMENTS
COVER CROP SELECTION
LOADING RATE DETERMINATION
a) HYDRAULIC
b) ORGANIC
c) NUTRIENT (N,P)
d) INORGANIC
SELECTION OF LIMITING LOADING RATE
DETERMINATION OF HYDRAULIC APPLICATION RATES AND IRRIGATION SCHEDULES
DETERMINATION OF BUFFER ZONE REQUIREMENTS
LAND-FORMING REQUIREMENTS
EFFLUENT COLLECTION
STORAGE REQUIREMENTS
DISTRIBUTION SYSTEM DESIGN
MONITORING REQUIREMENTS

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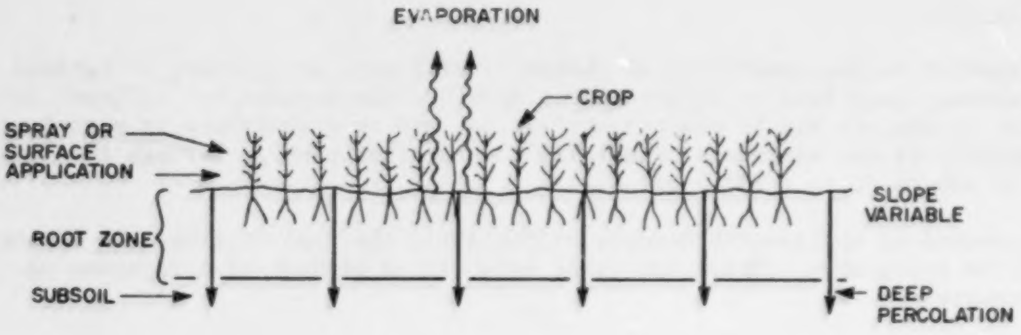
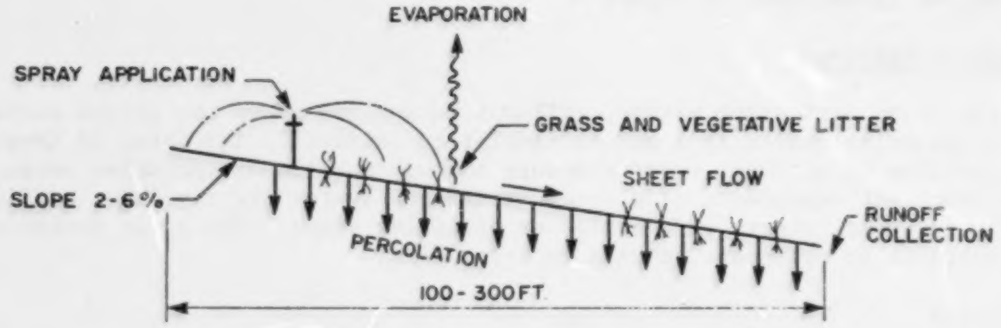
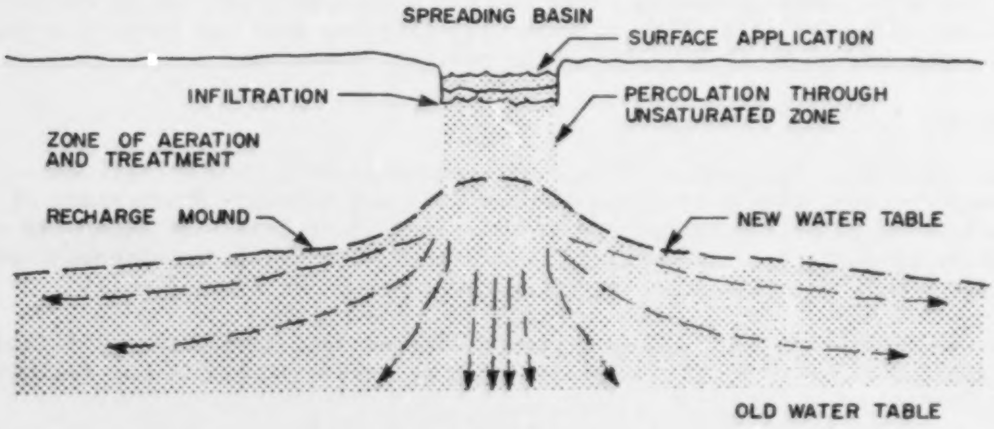
Figure 1. Flow diagram of the decision making process.



IRRIGATION



OVERLAND FLOW



INFILTRATION PERCOLATION

Figure 2. Surface land application approaches.

Irrigation

Irrigation is the controlled discharge of effluent, by spraying or surface spreading, onto land to support plant growth. The wastewater is "lost" to plant uptake, to air by evapotranspiration, and to groundwater by percolation. Treatment of the wastewater generally occurs after passage through the first 60 to 120 cm (2 to 4 feet) of soil.

The method of application depends on the soil, the type of crop, the climate, and the topography. There are three established methods of irrigation of wastewater:

a) spray irrigation
b) flooding
c) ridge and furrow

These are illustrated in Figure 3.

Spray Irrigation

In the spray irrigation method, effluent is applied above the ground surface by a sprinkler system in a manner similar to rainfall. The spray is developed by the flow of effluent under pressure through nozzles or sprinkler heads. The important components of a spray irrigation system are the pump, supply main, laterals, risers and nozzles or sprinkler heads. The spray system can be portable or permanent, moving or stationary.

Flooding

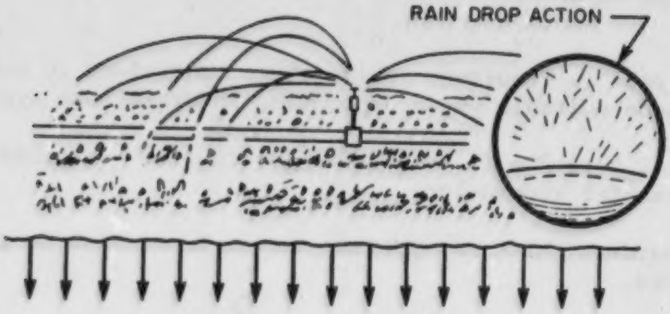
Flooding is the inundation of the land with effluent. The depth of inundation is determined by the slope, choice of vegetation and the type of soil. The land has to be level or nearly level so that a uniform depth can be maintained. The land needs drying periods so that soil clogging does not occur and the cover crop has to be able to withstand periodic flooding.

Ridge and Furrow Irrigation

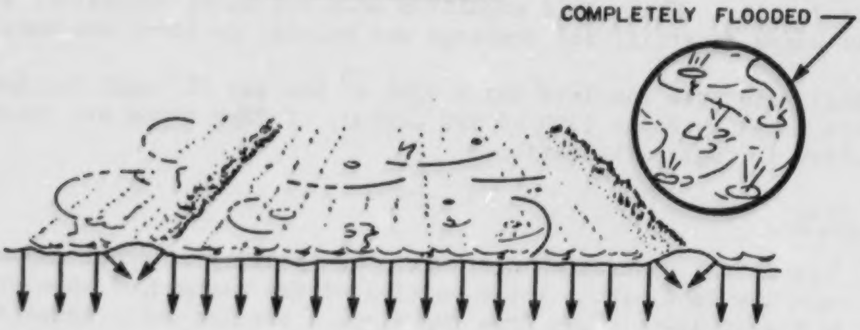
Ridge and furrow irrigation is accomplished by gravity flow of effluent through furrows, with subsequent seepage into the ground. Utilization of this technique is generally restricted to relatively flat land, and extensive preparation of the ground is required to create ridges and furrows whose width and depth vary with the quantity of wastewater and the type of soil.

Although irrigation is the most common method of land application utilized, its applicability to a particular location is most suitable if the following site conditions exist:

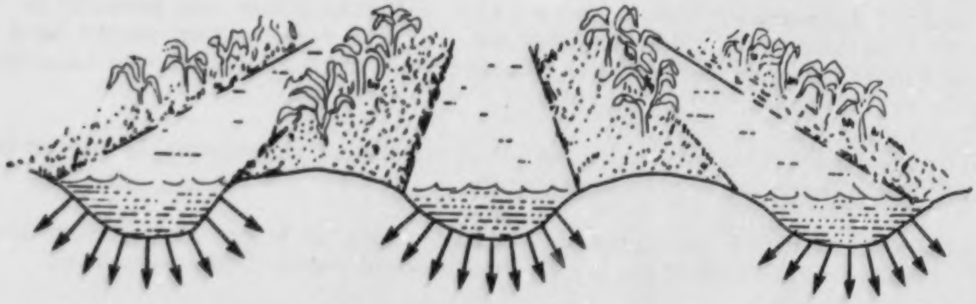
1. Warm arid climates are ideal. More severe climates are acceptable if facilities are provided to handle freezing and/or wet conditions.
2. Slopes up to 15 percent are acceptable provided runoff or erosion is



SPRAY IRRIGATION



FLOODING



RIDGE & FURROW

Figure 3. Methods of irrigation.

controlled.

3. Loamy soils are ideal but most soils from sandy loams to clay loams are suitable.

4. Well-drained soil is required. Where these conditions do not exist the site may be made suitable by incorporating underdrainage systems.

5. Soil depth of 1.5 to 2 m (5 to 6 feet) is required for plant root development and wastewater renovation.

6. Geologic formations which may provide direct connection to groundwater must be avoided.

7. A minimum depth to groundwater of 1.5 m (5 feet) is required to maintain aerobic conditions, provide wastewater treatment and prevent surface water-logging. Where this condition does not exist naturally, groundwater pumps or artificial drainage may be used to lower the water table.

8. Typical land area required for a 4540 m^3 per day (1 Imgd) irrigation system is 40 to 80 ha (100 to 200 acres). Buffer zones are frequently required for spray irrigation.

Overland Flow

Overland flow is the controlled discharge, by spraying or other means, of effluent onto the land with a large portion of the wastewater appearing as runoff. As the effluent flows down the slope a portion infiltrates into the soil, a small amount evaporates and the remainder flows to collection channels. Wastewater treatment occurs by filtration of suspended solids by surface vegetation and by oxidation of the organic matter by the bacteria living on the vegetation litter.

Soils limited in permeability such as clays and clay loams are especially suited to overland flow. The land for an overland flow system should have a moderate slope (between two and six percent) and the surface should have no mounds or depressions.

The following conditions are necessary for a site to be especially suitable to overland flow treatment of wastewater:

1. Soils with minimal infiltration capacity such as heavy clays, clay loams, or shallow soils underlain by an impermeable subsoil are suitable.

2. A minimum topsoil depth of at least 15 to 20 cm (6 to 8 inches) is recommended in order to establish a cover crop.

3. Slopes of 2 - 4% are required to allow the applied wastewater to flow slowly over the soil surface to the runoff collection system.

4. Warm arid climates are ideal. More severe climates are acceptable if

facilities are provided to handle freezing and/or wet conditions.

5. If reuse of the runoff is not possible, then a waterway or drainage system must be constructed to transport the effluent from the site. This effluent must meet the federal and provincial standards for discharge into receiving waters.

6. A minimum depth to groundwater of 1.5 m (5 feet) is required to maintain aerobic conditions for plant growth. Where this condition does not exist naturally, groundwater pumping or under drainage may be used to lower the water table.

7. Land requirements typically range from 10 to 45 ha (25 to 110 acres) for a 4540 m^3/day (1 Imgd) spray irrigation system; additional buffer zones may be required.

Infiltration Percolation

The infiltration percolation method of wastewater treatment is similar to intermittent sand filtration. The major portion of the wastewater enters the groundwater although there is some loss to evaporation. Soils with high infiltration and permeability rates such as coarse textured sands, loamy sands or sandy loams are required.

This process has been developed for groundwater recharge and thus the distinction between treatment and disposal for this process is quite fine. Some treatment occurs during the infiltration percolation process as the wastewater passes through the aerobic layer. The primary purpose of this method is to provide physical removal of suspended solids and bacteria.

The applicability of infiltration percolation for land application treatment of wastewater is quite restricted mainly because of soil permeability constraints. The following discussion summarizes the major criteria for the suitability of infiltration percolation treatment:

1. Well-drained soils such as sand, sandy loams and loamy sands are required. Very coarse sand and gravel are not ideal because they allow wastewater to pass too rapidly through the first few feet where the major biological and chemical wastewater treatment occurs.

2. A minimum depth to groundwater of 4.5 m (15 feet) is recommended. Where this condition does not exist naturally, groundwater pumping or artificial drainage may be used to lower the water table.

3. The site should be flat or gently sloping. Too much slope may create lateral percolation.

4. Land requirements typically range from 1 to 2 ha (2.5 to 5 acres) for a high-rate system to 8 to 24 ha (20 to 60 acres) for a low-rate system for a 4540 m^3/day (1 Imgd) wastewater application rate.

TREATMENT MECHANISMS

The design and successful operation of any wastewater treatment plant is predicated upon an adequate analysis of the wastewater being treated and upon an understanding of the treatment processes to be employed. In land application systems wastewater treatment and removal occurs at or below the soil surface. The efficiency of treatment and removal is reflected by soil-plant system characteristics, wastewater constituents and by the atmospheric climate.

Physical Processes

Many complex physical, chemical and biological processes take place to change the characteristics of wastewater applied to a soil.

Filtering or retention of solids close to the soil surface is the major physical treatment process. The size of particles removed is a function of the soil pore size and configuration and of the nature of the particles in the wastewater. The larger suspended solids are removed from the wastewater but bacteria and viruses can travel considerable distances through soils. It should be pointed out, however, that overloading with suspended material and the subsequent creation of anaerobic conditions may have adverse effects on the hydraulic capacity of the system.

The relative importance of soil physical processes in wastewater treatment and removal is a function of the land-application technique:

1. In irrigation systems, water removal by the soil physical processes is as important as the chemical and biological processes also taking place.

2. For overland flow methods of wastewater treatment, the soils are usually quite impermeable and very little wastewater infiltration results. Filtering of solids at the soil surface is therefore minimal.

3. In infiltration percolation systems, filtration of suspended organic matters from the wastewater is a very important wastewater renovation process.

Chemical Processes

Two important chemical soil processes partially responsible for wastewater treatment are adsorption and chemical precipitation. Soils containing clay or organic matter attract and retain (adsorb) ions possessing a positive charge (cations). The ability of the soil to adsorb cations is important to plant growth and wastewater treatment. For example, important plant nutrients such as potassium and ammonia which are usually present in significant concentrations in wastewater can be retained on soil particles for adsorption and made available for plant nutrition rather than leaching rapidly through the root zone and eventually to the groundwater.

Chemical precipitation reactions involving dissolved ions and other chemical compounds are numerous and exeedingly complex. Calcareous soils, common in the prairies or in limestone-derived soils can neutralize acidic wastes although this may result in the release of relatively soluble salt solutions. The principal mechanism for removal of phosphorus from wastewater in the soil is chemical precipitation.

Biological Processes

The most important mechanisms of wastewater treatment in the soil involve biological transformation. Some of the groups of soil organisms responsible for the decomposition of plant and animal materials are bacteria, fungi, actinomycetes, protozoa, worms and insect larvae. These organisms alter waste constituents and a high proportion of the chemical constituents, notably carbon, nitrogen, phosphorus and potassium, are liberated for plant growth.

Aerobic decomposition of new organic material may be considered to take place in three stages:

1. Organisms initially digest the more easily decomposed material, consuming oxygen and releasing carbon dioxide and water. The amount of oxygen consumed can be estimated by the five day biochemical oxygen demand test. Organism growth rate is rapid during this stage.

2. The number of organisms declines as the readily decomposed organic material is consumed. The dead microbial tissue, together with the intermediate decay products provide substrate for new and remaining organisms. This material, together with the more refractory organics in the wastewater are degraded to a relatively stable end product known as humus.

3. The organisms decline to population levels similar to those before addition of the wastewater. However, decomposition of humus by highly specialized organisms continues during this phase.

The rate of organic matter decomposition and the nature of the intermediate and end products depend on the composition of organic matter. Soil factors, however, also exert considerable influence. The presence or absence of adequate oxygen in the soil is the principal factor in determining the rate of decomposition and the end products.

Decomposition also occurs under anaerobic conditions but at a slower rate and often with the production of intermediate compounds having objectionable odours. Plant growth will likely suffer under prolonged anaerobic conditions. Intermittent or partial anaerobic conditions may result in the production of nitrogen gas and various other gaseous oxides of nitrogen. This reaction and the volatilization of ammonia can reduce problems of nitrogen overloading to some extent.

DESIGN VARIABLES

Soil Characteristics

The foregoing discussion of physical, chemical and biological treatment processes illustrates the interacting soil, cover crop, wastewater and climatic characteristics in wastewater treatment. Important soil characteristics in the selection and design of land application systems include the following:

1. infiltration rate
2. permeability
3. available water capacity
4. cation exchange capacity
5. depth to groundwater

Infiltration rate is a soil surface phenomenon which describes the rate of water movement into the soil surface. It is a direct function of soil pore size and moisture content.

During initial wastewater application, the application rate is controlled by the infiltration rate. The infiltration rate decreases, however, as application continues and approaches a limiting value. At saturation, this constant is equal to the permeability of the least permeable soil layer.

Most screening of suspended material from wastewater occurs during infiltration. However, the high concentrations of suspended solids present in some food processing wastewaters may clog surface soil pores. Application of wastewater at rates beyond the infiltration rate for long periods of time results in anaerobic conditions.

Compaction of the soil surface by water droplets in a spray irrigation system may greatly reduce pore space volume and seal the surface to downward water movement. The presence of a cover crop to cushion the impact of water droplets usually alleviates this problem.

Infiltration rate is an important variable in irrigation and infiltration percolation systems. Wastewater application rates which exceed infiltration rates and thus produce ponding or surface runoff should be avoided. Periods of wastewater application should be followed by rest periods to allow the surface to dry and prevent the persistence of the anaerobic conditions which give rise to surface clogging.

Permeability describes the rate at which water and air move through the subsoil. It is controlled both by soil texture and structure and is primarily a function of pore size. Fine textured and structured soils generally possess low permeability; medium textured and structured soils such as loam or silty loam tend to have moderate to low permeability. Coarse sands exhibit the highest permeability. Table 1 summarizes typical permeability rates for various soils.

Those soils having severely restricted permeability in the lower part of the profile are likely to develop a perched water table and tile drains may be required. Soils having large pores or fractures transmit water and air rapidly but may also transmit contaminants.

Conditions of extreme impermeability in the subsoil horizon may result from layers of impervious clay beds or rock formations located within several feet of the soil surface.

TABLE 1. TYPICAL RANGES OF PERMEABILITY AND AVAILABLE WATER CAPACITY ACCORDING TO SOIL TEXTURAL CLASS (1)

	Permeability (cm/hr)			Available Water Capacity
	0 to 3%	3 to 9%	Greater than 9%	(cm/m)
Very coarse textured sand and fine sands	2.5 or greater	2 or greater	1 or greater	4 to 8
Coarse textured loamy sands and loamy fine sands	2 to 4	1 to 2.5	1 to 2	6 to 10
Moderately coarse textured sandy loams and fine sandy loams	1 to 2.5	1 to 2	0.8 to 1	10 to 15
Medium textured very fine sandy loam, loams and silt loams	0.8 to 2	0.5 to 1	0.4 to 0.8	13 to 20
Moderately fine textured sandy clay loams and silty clay loams	0.5 to 1	0.4 to 0.6	0.3 to 0.4	15 to 20
Fine textured sandy clays, silty clays and clays	.3 to .5	.3 to .4	<0.3	13 to 20

It is emphasized that the infiltration and permeability rates are important in the selection of methods for wastewater treatment:

1. Soils with high infiltration and permeability rates are suitable for infiltration percolation wastewater treatment.

2. Soils exhibiting very low infiltration and permeability rates can only support overland flow systems.

3. Soils exhibiting moderate infiltration and permeability rates are suitable for irrigation systems.

The available water capacity is defined as the amount of water retained by a soil between the field capacity and the wilting point. Its magnitude determines the quantity of water which can be stored in the soil for uptake by plant roots and it reflects the quantity of wastewater that can be held in the soil without being discharged into the groundwater.

Available water capacity depends on soil pore size and shape and the strength of bonding of the water to soil particles. Soils can be divided into three groups, depending on the texture (typical ranges of available water capacity are given in Table 1).

1. Coarse texture - low water capacity because of large pores and low surface area; readily drained by gravity.

2. Medium texture - high available water capacity with relatively small pores and medium retention of water.

3. Fine texture - low available capacity due to large areas and tightly bonded water.

Cation exchange capacity is a measure of the ability of a soil to retain positively charged ions such as the ammonium ion, calcium, magnesium, potasium and sodium. Both the clay and humus fractions of the soil are characterized by extremely small particle size and by the presence of a negative electrical charge. The significance of this charge is that oppositely charged ions or compounds are attracted and held to these colloidal surfaces. The size of the soil colloids and the magnitude of the electrical charge determines the cation exchange capacity of a soil.

The cation exchange capacity serves as a rough index of reactions which occur between pollutants and the soil surfaces. In general, the greater the cation exchange capacity of a soil, the greater the potential for effective waste treatment.

The groundwater table is the level in the soil at which free water is present. Above this level, free water movement is vertically downward. At the groundwater table the soil becomes saturated and water movement becomes vertical and lateral.

The depth of the soil to groundwater is a major factor in determining water storage and hence the surface water removal capacity of a land application system. In addition, it determines the distance the wastewater will travel through the aerobic zone where potential contaminants can be filtered out or removed by biological and chemical mechanisms before the groundwater is reached.

The variation of depth to groundwater throughout the site and variation with season should be determined prior to the selection of the site and the land application method. In order to ensure an aerobic root zone for cover crop growth, it is preferable to maintain a groundwater level at least five feet below the ground surface. Groundwater levels can be controlled by installing an underdrainage system or by pumping water from wells located close to the site.

Cover Crop Characteristics

The cover crop increases the capacity of the soil to accept and to treat wastewater. Plants protect the soil from erosion losses, encourage and maintain moisture infiltration, increase soil drying rates through transpiration and absorb nutrients. Vegetative cover also has an aesthetic appeal and may contribute an economic benefit through crop harvest and sale. Cover crop characteristics pertinent to the selection and design of land application systems are the following:

1. water requirements
2. nutrient requirements
3. tolerance of the plant to potentially harmful wastewater characteristics
4. management requirements
5. market value

As discussed previously, some of the wastewater which is applied to the soil is removed by natural drainage into and through the soil pore space. Plants provide an additional means for water removal up to several feet below the surface. Water moves into the plant roots and upwards to the plant body where moisture is lost from the leaves by transpiration. The transpiration rate is a function of climatic conditions including temperature, precipitation, solar radiation and wind. It also depends on the availability of soil moisture and on such characteristics as rooting depth and the seasonal pattern of root and leaf development. The removal of water by both evaporation and transpiration is described collectively as evapotranspiration. Important evapotranspiration factors associated with the cover crop include rooting depth, seasonal pattern of root and leaf development and other specific factors such as the physical nature and size of leaf growth.

Rooting depth increases in importance as the length of the resting period in the wastewater application schedule increases. As the surface layer of the soil dries, water will be drawn from successively greater depths. Plants such as alfalfa with deep rooting systems can also penetrate impermeable subsoil zones and thus increase the water infiltration capacity of the soil.

Nutrient removal through crop harvest is the primary mechanism of nitrogen and phosphorus removal from the soil and depends on the type of land application system. For example, in an overland flow system, both nitrogen uptake and denitrification play major roles in nitrogen removal. Phosphorus removal, however, is determined by plant uptake since adsorption by the soil is not significant. In contrast, the quantity of nutrients removed by plants may be minor compared to total loadings in an infiltration percolation system.

The quantity of nutrients which can be removed depends on the type of plant cover and the harvested yield. Figure 4 illustrates the potential for removal of nitrogen and phosphorus in various crops. Both nitrogen and phosphrous are absorbed in greatest quantities by certain species of grasses. Harvesting the entire cover crop (for example, corn silage, hay) results in greater nutrient removal than harvesting only selected parts (grain, vegetable crops) and ploughing the remaining vegetation into the soil.

Certain chemical constituents of wastewater may be toxic to vegetative growth. The elements of possible concern in food processing wastewaters include sodium, calcium and magnesium, and various salts such as chloride, sulfate and bicarbonate.

The effect of saline solution on plant growth is principally due to changes in the osmotic pressure of the solution which influences water availability to the plant roots. In addition, high concentration of ions such as chlorine may interfere with nutrient assimilation by plants. Plant species differ in their responses to salinity.

The ability of the cover crop to adapt to a specific land application system and the labour requirements for successful crop management are important factors in selecting a cover crop. The following factors need to to be taken into account:

1. Tolerance to variable soil moisture conditions, especially frequent saturation.

2. Soil physical and chemical properties.

3. Tolerance to severe climatic changes such as low temperatures and the plant growing season.

Assistance in the selection of crops can normally be obtained from local agricultural representatives.

Labour requirements for successful crop management may be critical during all stages of crop growth. These include germination, emergence, and seedling establishment in which favourable soil and moisture conditions are critical for some crops.

During the growth period, important management factors may include supplemental fertilization, well defined tillage practices, irrigation scheduling, weed and insect control and crop harvesting. It may also be necessary to re-establish or rotate crops from to time when visual checks or yield tests indicate

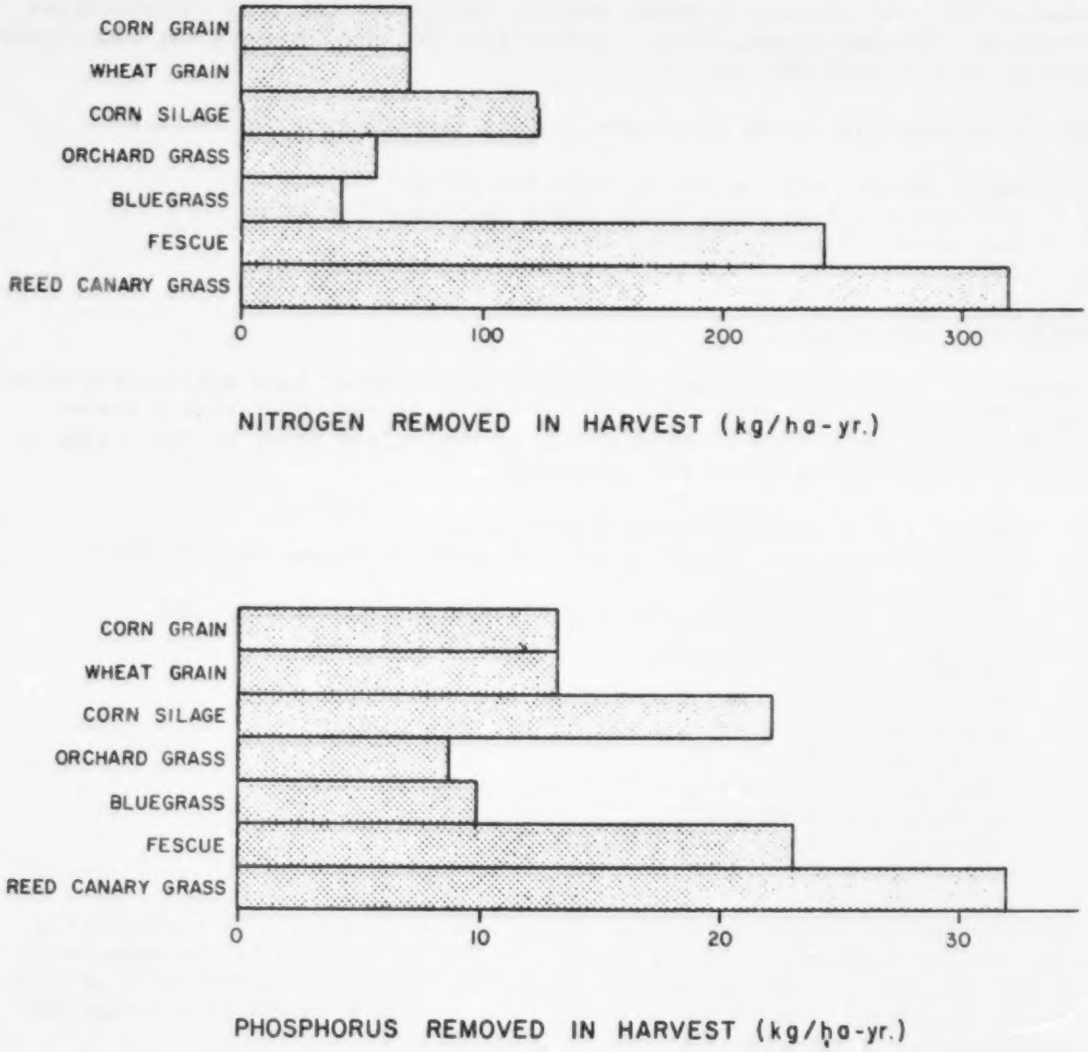


Figure 4. Potential nutrient removal by crops.

poor productivity. Specific cover crop requirements and limitations are discussed later in this section.

The economic return from certain crops may offset some of the operating costs of a land application system. The return may be substantial in arid regions because the availability of water permits the growth of crops not otherwise possible. In such areas, limited competition in local markets may add significantly to this monetary return.

The following cover crops have been used in land-application systems:

1. Small grains, such as wheat, oats and barley
2. Row crops such as corn, sugar beets and vegetable crops
3. Sod crops, primarily grasses and legumes
4. Forests

Wastewater Characteristics

Wastewater characteristics may affect the selection of land application methods and they will usually affect the efficiency of operation of such a system. Wastewater characteristics which should be determined prior to the design of a land application system are the following:

1. Annual and seasonal wastewater quantities
2. Biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD)
3. Suspended solids (SS)
4. Total dissolved solids (TDS) and electrical conductivity (EC)
5. Nitrogen (N)
6. Phosphorus (P)
7. pH
8. Temperature
9. Color
10. Toxic elements (heavy metals, trace elements, etc.)
11. Bacteria and viruses
12. Sodium adsorption ratio (SAR)
13. Oil and grease

The seasonal and annual quantities of wastewater generated by a processing plant will determine the area of land required to dispose of the wastewater. In addition, since wastewater produced during the winter months will usually have to be stored, quantities generated during those months will determine storage volume requirements.

The biochemical oxygen demand (BOD_5) is a measure of the concentration of readily oxidizable organic matter in the wastewater. When the rate of application of organic matter exceeds its rate of removal by soil micro-organisms, clogging of the soil surface may result,thus greatly reducing the wastewater infiltration rate and producing anaerobic conditions within the soil which greatly decrease the efficiency of treatment.

Suspended solids in wastewater may cause operational problems such as clogging of sprinkler nozzles and soil pores, and the formation of an impermeable coating over the soil surface.

An excessive rate of application of high TDS bearing wastewaters may cause a salinity hazard to crops and/or may cause groundwater contamination. The salinity hazard to crops can be especially prevalent in arid or semi-arid regions where the annual evapotranspiration exceeds annual precipitation. Table 2 summarizes some of the effluent quality requirements for land application systems.

Nitrogen and phosphorus may be present in relatively high concentrations in some wastewaters, especially those from meat and poultry processing plants. Although both are important plant nutrients, when applied at excessive rates, they may contaminate the groundwater.

Wastewaters having a pH between 6.0 and 9.0 are generally suitable for application to the land since microbial and plant processes are generally most active in the neutral pH range (6 to 7).

The application of high temperature wastewater (greater than 150°F) to land may sterilize the soil and thus prevent the growth of any vegetation.

In most wastewaters colour is associated with degradable organic material and is effectively removed as the water percolates through the soil mantle. However, should the colour associated with the wastewater be persistent such as that associated with lignins, it can leach into the groundwater and effectively contaminate this water source. This type of groundwater contamination is difficult to avoid and therefore coloured wastewaters to be applied to the land should be carefully assessed for ease of colour removal.

Meat and poultry processing wastewaters usually contain significant concentrations of pathogenic bacteria and viruses. Although the soil mantle is usually quite efficient in the removal of bacteria and viral organisms, some concern has been expressed recently because of confirmed viral infection resulting from land application of wastewaters. When a spray application system is to be utilized, consideration should be given to the possible transportation of pathogens in aerosols.

The relationship between the principal cations in wastewater, especially calcium, magnesium and sodium is very important. When the ratio of sodium to calcium and magnesium (expressed as sodium adsorption ratio) becomes too high, the sodium tends to replace the calcium and magnesium ions on clay particles and has the effect of dispersing the soil particles and consequently reducing soil permeability.

Wastewaters from meat and poultry processing plants usually contain relatively high concentrations of oil and grease from cutting, deboning and rendering operations. Excessive concentrations may cause severe clogging of the soil pores.

TABLE 2. EFFLUENT QUALITY GUIDELINES(3)

Problem and Related Constituent	Guideline Values		
	No Problem	Increasing Problems	Severe
Salinity[1]			
EC_e of irrigation water, in mmho/cm	less than 0.75	0.75 to 0.30	greater than 3.0
Permeability			
EC of irrigation water, mmho/cm	greater than 0.5	less than 0.5	less than 0.2
SAR (Sodium adsorption ratio)	less than 0.6	6.0 to 9.0	greater than 9.0
Specific ion toxicity[2]			
From root adsorption			
Sodium (evaluate by SAR)	less than 3.0	3.0 to 9.0	greater than 9.0
Chloride, me/l	less than 4.0	4.0 to 10	greater than 10
Chloride, mg/l	less than 142.0	142 to 355	greater than 355
Boron, mg/l	less than 0.5	0.5 to 2.0	2.0 to 10.0
From Foliar adsorption[3] (Sprinklers)			
Sodium, me/l	less than 3.0	greater than 3.0	-
Sodium, mg/l	less than 69.0	greater than 69.0	-
Chloride, me/l	less than 3.0	greater than 3.0	-
Chloride, mg/l	less than 106	greater than 106.0	-

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[1] Assume water for crop plus needed water for leaching requirements will be applied. Crops vary in tolerance to salinity.

[2] Most tree crops and woody ornamentals are sensitive to sodium and chloride (use values shown). Most annual crops are not sensitive.

[3] Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to sodium or chloride adsorption under low-humidity, high-evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations or sprinkler heads).

Note: Interpretations are based on possible effects of constituents on crops and/or soils. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil, and method of irrigation.

Climatic Characteristics

The magnitude of climatic effects in the design of land application systems depends on the category and method of application, the type of equipment used and the volume of wastewater applied. The major climatic variables are the following:

1. Seasonal and annual distribution of precipitation
2. Average seasonal temperatures
3. Speed and direction of prevailing winds

Precipitation in the form of rainfall, snow and hail will serve to determine allowable wastewater loading rates, storage requirements and land drainage requirements.

During the application season, the land area must be sufficient to dispose of incident seasonal precipitation as well as of applied wastewater. Therefore, a water budget for a proposed system must take account of all precipitation during the wastewater application period. All storage facilities must be sufficient to contain any incident precipitation and runoff produced during non-application periods.

The ambient air temperature affects wastewater loading rates and determines the allowable length of the application season. The rates of soil microbial reactions are temperature dependent. The rate of removal of water from the soil and cover crop by evapotranspiration is a function of several variables including precipitation, wind, availability of soil moisture and vegetation characteristics. However, temperature is the single most important variable. Finally, cover crop growth patterns are controlled as much by temperature as by moisture availability.

The prevailing wind directions and speed are important where spray irrigation is used and aerosol drift to nearby communities may be a problem. These wind data are useful in predicting buffer zone requirements around the wastewater treatment facility. In addition, prevailing wind direction should be considered where odour transmission is a potential problem, particularly from stored effluents.

PROCESS DESIGN

Figure 1 summarizes the various steps in the design of a land application system. Following a preliminary assessment of site characteristics and constraints, one of the three methods of land application discussed earlier should be selected. This section summarizes briefly the various design components for each of the systems.

Pretreatment Requirements

Pretreatment requirements for food processing wastes may include one or more of the following processes:

1. Coarse screening for suspended solids removal
2. pH adjustment
3. Deodorization
4. Biological pretreatment

Coarse screening may be required for removal of solids which clog spray nozzles or for the removal of grit which may accelerate the erosion of pumping and transmission equipment.

The three types of screens normally used include stationary, vibrating and rotating screens.

pH adjustment is required for those wastewaters whose pH is outside the range of 6 to 9.5. Typical chemicals used include sodium hydroxide and sodium carbonate for acidic wastewaters, and sulphuric and hydrochloric acid for alkaline wastewaters.

Wastewater effluent may be deodorized prior to irrigation in those cases where odour problems exist.

Biological pretreatment may be required by the provincial regulatory agency involved in approving the facility. Biological treatment processes which have been used include anaerobic lagoons, facultative and aerated lagoons, activated sludge, oxidation ditches, trickling filters and rotating biological contactors.

Cover Crop Selection

The choice of a suitable cover crop will depend on one or more of the following objectives:

1. Maximum water removal
2. Nutrient removal
3. Economic return

Sod crops such as legumes and grasses have a longer growing season than grain or row crops and therefore provide increased consumptive use of water. Forests also hold the potential for removing relatively large volumes of water.

Sod crops, row crops and grain crops provide good nutrient removal. Grain crops and row crops may be used to maximize the economic benefits of a land application facility.

Loading Rate Determination

The importance of regulating the liquid loading rate, the effects of overloading and the climatic constraints to seasonal and annual wastewater application rates were discussed earlier. Soil permeability and climatic evapotranspiration data should be used to determine the hydraulic loading rates for the site. These rates can then be used to determine land areal requirements and to set up an irrigation schedule.

The wastewater application rate may be limited by the concentration of nitrogen and/or phosphorus in the wastewater. The nutrient loading rate to the soil must be limited such that a balance is reached between the amount applied, the amount removed by treatment and crop uptake and the concentration permitted to reach the groundwater.

The effects of organic overloading to the soil were discussed earlier. Wastewater application rates should not be so high that clogging of the soil surface occcurs due to excessive organic application rates.

In most cases either the hydraulic or the nutrient loading rate to a particular soil will determine the allowable wastewater application rate. Once the rate has been established, an application cycle is determined. Application rates are normally expressed as the quantity of wastewater applied per cycle. The duration of the wetting or application period and the application rate during each cycle are determined by the method of application used. Resting or drying periods following the wetting period are usually necessary to re-establish aerobic conditions in the soil. The optimum drying period is a function of the land application method and is also very site specific.

Buffer Zone Requirements

When a spray irrigation facility is located near populated areas, a buffer zone is recommended, especially downwind of the sprinkler. In some cases, this may involve scheduling the location of application such that the buffer zone downwind of the application site is a portion of the field.

In other cases, buffer zones from 15 to 60 m wide around the perimeter of the site have been utilized. Provincial regulations may require buffer zones in excess of these.

Land Forming Requirements

Land forming requirements are usually minimal for spray irrigation but are important in flood irrigation and ridge and furrow irrigation systems. Formation of basins is usually required for infiltration percolation systems and surface alterations may be required in overland flow systems to provide adequate slope and soil surface characteristics.

Underdrainage Effluent Collection

A subsurface drainage system may be required to prevent excessive groundwater buildup or to intercept the effluent and collect it for further treatment prior to discharge.

Storage Requirement

Storage of wastewater may be required under one or more of the following conditions:

1. Seeding and harvesting the cover crop

2. Precipitation requiring the temporary reduction or cessation of application

3. Winter weather requiring reduction of winter application rates

4. Winter weather requiring cessation of operation

When reduction or cessation of operation resulting from winter weather is expected, storage requirements should be based on the maximum expected freezing period. Temporary wastewater storage may be necessary during the application season when excessive rainfall prohibits normal application. The size of the storage basin must be sufficient to contain anticipated precipitation during the storage period in addition to the wastewater.

Distribution System Design

The distribution system consists of facilities for transmission to the site and facilities for application at the site including pumps, distribution mains and laterals, flow control valves and outlets such as sprinklers for spray irrigation systems or gates for flood irrigation.

Transmission to the site can be by pressure or gravity. Velocities in the transmission main should be between 2.5 and 3 metres per second. Gravity mains should be at the low end of the range and force mains should be in the middle to upper range. Where velocities are too high, excessive losses occur at bends and valves.

The distribution system is the most complex component of any land application facility; its design will not be discussed in this paper. Irrigation handbooks such as that by Pair(4) provide the pertinent hydraulic design information.

Monitoring Requirements

A monitoring program may be required to ensure that proper wastewater treatment is being carried out and that environmental degradation is not occurring. Secondly, monitoring of the cover crop may be useful to optimize its growth and yield. Finally, since application of wastewater to land is likely to cause some changes in soil characteristics, periodic monitoring of soil salinity levels, pH and cation exchange capacity should be practiced.

LABORATORY AND PILOT EXPERIMENTS

Laboratory and/or pilot plant experiments can be useful in investigating some of the technical aspects of the application of wastewater to land. Although considerable information can be obtained from these studies, caution is advised since the experimental conditions may be somewhat artificial. Greenhouse germination tests or growth chamber tests and onsite pilot scale studies can all be used as part of the predesign activity to assess the practicality of land treatment for a specific site.

Germination tests may be useful to detect potentially acute toxicity resulting from the application of wastewater. The test is a comparison of germination of seeds in soil moistened with wastewater to that in soil moistened with tap water.

Greenhouse experiments are used to assess plant responses to the application of wastewater. These experiments may be carried out by comparing plant growth from wastewater application with that from tap water application. The plant tissue and soil can be subjected to chemical and physical analyses after harvesting.

These experiments require facilities for plant growth and analysis, and several months of laboratory or greenhouse experimental time.

Onsite pilot studies can provide valuable design data (wastewater application rates and soil capacities), particularly where the topography and soil type do not clearly favour one category of application over another.

Pilot studies should be conducted on representative plots, approximately 0.5 hectare in area. Flat plots may be defined by plowing a furrow around the perimeter and mounding the soil around the edges. Sloping plots suitable for overland flow systems will require a cleared ditch with a flow-measuring device (Parshall flume or V-notch weir) at the base of the slope. A network of wellpoint piezometers should be installed in and around flat areas and those sloping areas with high permeability to monitor changes in water table and groundwater quality.

CONCLUSION

For most land application systems, a wide range of design possibilities is available to suit specific site characteristics, climate, treatment requirements, and project objectives. In addition, a wide range of design possibilities is available for each site. The designer must rely on a comprehensive understanding of the treatment principles involved, site evaluation by specialists and his own ingenuity. When proper attention is given to the design of such facilities, land application systems hold a great deal of potential for the treatment of effluents from food processing plants since these wastewaters are generally non-toxic and easily biodegradable.

ACKNOWLEDGELMENTS

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USING MICROWAVES TO REDUCE POLLUTION FROM SCALDING CHICKENS

by

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The traditional method of achieving feather release of poultry in the slaughtering process is by scalding, which consists of applying moist heat to the skin to reduce the force required to pull the feathers. It is usually accomplished by immersing birds in or spraying them with water at temperatures ranging from 54°C for broiler chickens up to 60°C for fowl and turkeys. The objective is to loosen the feathers to permit their removal by mechanical pickers.

Research by Gwin(1) (2) (3) indicated marked advantages for scalding in reducing labor costs of pinning and in assuring a completely feather-free bird. Pool et al.(4) investigated the effects on feather release when live birds were injected with reserpine. The force required to pull the feathers from the treated birds was impressively reduced after 18 hours, but the pre-injection force required returned almost immediately after the birds' death. Other methods were also studied, including the effects of radiant heat, brain sticking, and administration of sodium barbitol. Klose(5) suggested that aesthetic and product safety considerations encourage the replacement of immersion-type scalding; however, the development of commercially feasible alternatives has been hampered by economic and engineering problems. Alternatives that have been considered include spray or steam scalding and a combination of the two.

The major limitations of the scalding method are: (a) the large quantity of water required (about one quart per bird); (b) the amount of energy necessary to heat the water (about 200 BTU's per bird); and, (c) the process involved in disposing of the polluted water that results.

Increasing attention has been directed to these limitations because of rapidly escalating costs of energy, the increasing scarcity of potable water, societal concerns for environmental quality, and consumer interest in product quality. Thus, a need exists to find an alternative system that avoids the shortcomings of the scalding method for achieving feather release. After Miller(6) used a home microwave unit, he concluded that the method might be feasible to achieve feather release but the results were inconsistent.

The purpose of this study was to investigate further whether exposure of broilers to microwave energy would release feathers satisfactorily from the different feather tracts and whether, as a consequence, underlying tissue would be adversely affected.

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PROCEDURE

Broiler chickens ranging in age from 8 to 12 weeks were used in this experiment. Of the 242 broilers used, 233 were treated with microwave energy. They were assigned a random number from 1 to 20, representing predetermined exposure times. The nine remaining birds served as controls: five of them were scalded by immersion in hot water and four were untreated.

The control group treated by scalding was immersed in water at a temperature of 61°C for about 1.5 to 2.0 minutes. Then an incision was made in the feather tract, and a thermometer was inserted to measure the tissue temperature. The force necessary to pull the feathers as a consequence of scalding was measured with a Dyne-Newton scale equipped with a clamp on the end of a rod that was attached to a feather or group of them. As the bird was pulled manually away from the scale at a uniform rate, the scale moved a relatively friction-free pin around the dial. When the feather was released, the dial needle that indicated the force quickly returned to zero, leaving the frictionless pin stationary at the point of maximum force.

From the data on the control group of birds treated by scalding, the maximum force acceptable to achieve feather release was determined to be 3.5 Newtons. This measurement was used as an evaluative criterion for the effectiveness of microwave treatment.

The birds treated by microwave energy were placed in a commercially available unit that had a 0.9-meter cubicle chamber containing a carousel-type mode stirrer to provide uniform exposure. The unit also contained a power meter to register the amount of energy that entered the chamber at any given time.

The birds were exposed individually by suspending them by the feet from a plastic shackle in the microwave chamber. Each one was subjected to microwaves for the specified assigned time at a fixed power level for its respective treatment group. The power levels selected were 500, 1500 and 2000 watts. Exposure times ranged from .25 to 2.0 minutes at .25-minute intervals.

Upon completion of the microwave treatment, the temperature of the tissue and the pulling force required to remove the feathers were determined for each bird by the same procedure that was used for the scalded control birds. The feather release force was measured for each of the feather tracts (e.g., humeral, alar, ventral, spinal, femoral, crural, and caudal). Tissue damage was determined by a visual examination of underlying tissue after exposure.

A discriminate analysis was statistically performed to distinguish between feather release versus non-release and tissue damage versus no damage.

RESULTS AND DISCUSSION

After the first 20 birds were exposed to microwaves, it was found that the power necessary to achieve satisfactory feather release from femoral, spinal, and ventral tracts caused extensive tissue damage to the alar, caudal, crural, and humeral feather tracts. These findings suggested that the feather tracts required different levels of power and times for satisfactory feather release. A second group of 20 birds was similarly treated to provide sufficient data for statistical analyses. The Student t test was used to statistically analyze the data for each feather tract. The alar, caudal, crural, and humeral feather tracts evidenced no significant differences in the time or power level necessary for feather release without tissue damage. Similarly, it was found that the femoral, spinal, and ventral feather tracts had the same relative time and power requirements among themselves. The findings necessitated that the feather tracts be considered as two separate groups; one consisting of the alar, caudal, crural, and humeral (extremities) and the second consisting of the femoral, spinal, and ventral (torso).

The number of power levels originally planned also had to be reduced. Only the 1500- and 2000-watt levels were used for the remaining 193 birds because the 500-watt level was found to be ineffective, and the 2500-watt level was unattainable with the particular microwave machine that was used. The original exposure evaluation techniques were also modified to make judgmental decisions about feather release effectiveness and tissue damage resulting from microwave exposure. These decisions were made by comparing the effort required to pick feathers from each bird before and after exposure. Questionable results were verified with the Dyne-Newton scale. Visual examination for determination of tissue damage was continued.

The results from microwave exposure were classified into four treatment categories: Treatment 1 - the femoral, spinal, and ventral feather tracts exposed to 2000 watts of power; Treatment 2 - the alar, caudal, crural, and humeral feather tracts exposed to 1500 watts; Treatment 3 - the alar, caudal, crural, and humeral feather tracts exposed to 2000 watts; and Treatment 4 - the femoral, spinal, and ventral feather tracts exposed to 1500 watts.

The treated birds were further classified into three groups by discriminate analysis (Table 1): Group 1 - underexposed, with no feather release or tissue damage; Group 2 - optimum exposure, with feather release and no tissue damage; and Group 3 - overexposed, with feather release and tissue damage.

The findings indicated that satisfactory feather release can be obtained by exposing a bird to a predetermined level of microwave energy for a predetermined time. However, the alar, caudal, crural, and humeral feather tracts must be exposed for less time than the femoral, spinal, and ventral feather tracts. The problem is that the microwave unit cannot properly distribute the energy over a bird's body due to the unequal mass distribution of the bird. Theoretically, exposing the torso for a predetermined amount of time while shielding the extremities to prevent them from being cooked, then subsequently exposing the entire body to the microwave level necessary to release feathers from the extremities would be ideal. Such a procedure would permit all of the feathers to be released without any tissue damage.

From the data generated, equations were developed through discriminate analysis whereby, if a bird's weight is known, the time exposure to microwaves that would be necessary to achieve feather release at a constant power for each of the two groupings of feather tracts can be calculated.

TABLE 1. SUMMARY OF MICROWAVE EXPOSURE DATA ON CHICKENS

Treatment No.	Feather Tract Group*	Total Birds No.	Weight per Bird		Microwave Power (Watts)	Exposure Time (Min)		Exposure Results
			Kg	Std Dev		Avg	Std Dev	
1	1	14	2.22	0.59	2000	0.58	0.08	Underexposed
		23	2.13	0.50	do.	0.70	0.13	Optimum exposure
		18	1.95	0.57	do.	0.90	0.20	Overexposed
Total or Avg^{+}		55	2.09	0.58		0.74	0.19	
2	2	20	2.32	0.53	1500	0.37	0.09	Underexposed
		18	2.27	0.62	do.	0.53	0.09	Optimum exposure
		22	2.18	0.52	do.	0.77	0.16	Overexposed
Total or Avg^{+}		60	2.22	0.56		0.58	0.21	
3	2	18	2.18	0.82	2000	0.29	0.05	Underexposed
		19	2.38	0.57	do.	0.47	0.06	Optimum exposure
		20	2.18	0.61	do.	0.60	0.15	Overexposed
Total or Avg^{+}		57	2.27	0.70		0.46	0.16	
4	1	4	2.22	0.72	1500	0.50	0.00	Underexposed
		6	2.18	0.30	do.	0.93	0.24	Optimum exposure
		11	2.09	0.22	do.	1.20	0.28	Overexposed
Total or Avg^{+}		21	2.13	0.37		0.99	0.36	

*1 = Torso
2 = Extremity feather tracts

$^{+}$Weighted averages

It should be possible to get complete feather release with optimum exposure. However, some of the experimental birds of relatively equal weight that were subjected to the same treatment evidenced tissue damage, but comparable birds did not. Presumably the tissue damage resulted from differences in tissue water content. For example, birds with symptoms of breast blisters before exposure showed tissue damage in that area after exposure.

The results of this experiment indicated the feasibility of using microwave energy as a revolutionary approach to achieving feather release from chickens. Commercial application of the process might be accomplished by either: (a) weighing the birds before exposure and then subjecting different areas of the body to microwaves in accordance with the relationship of the weight to the proper time interval at a predetermined level of energy; or (b) predetermining the microwave exposure time, then weighing each bird and determining the energy level necessary for optimum exposure, thus allowing a processing unit to proceed at normal line speed. Either approach would likely require the use of a minicomputer on the line to make the determinations.

The potential energy saving from the microwave energy system over the traditional scalding system is substantial because microwave exposure would require only an estimated 132 BTU's per bird, whereas heating the one quart of water that is commonly used per bird would require about 200 BTU's. In addition, the use of microwave energy would reduce problems associated with disposal of the polluted water that results from the scalding process.

Our challenge is to develop equipment that will make the use of microwave energy economically feasible in commercial processing operations.

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ACTIVATED SLUDGE TREATMENT OF WASTEWATERS FROM THE DAIRY PRODUCTS INDUSTRY

by

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INTRODUCTION

Regulations and guidelines for controlling the liquid waste from the Canadian dairy industry are currently being developed by Fisheries and Environment Canada. In conjunction with the task force activity to identify the best practicable technology (BPT) for the treatment of dairy wastes, the Wastewater Technology Centre, Burlington, Ontario undertook a comprehensive sampling and monitoring program at three extended aeration activated sludge systems located at dairy plants in Southern Ontario. These systems were selected because they were considered to represent BPT or had the potential to be upgraded to represent BPT.

The program was carried out in June, July and part of August, 1977. These months represent the annual peak production period of the Canadian dairy industry.

Plant A produced ice cream, butter, powdered milk and ice products such as popsicles and flavoured ice. The major products of plants B and C were butter and powdered milk. Cheddar and Colby cheeses were also produced at plant B, however, whey generated from a cheese making operation was separated and sold as an animal feed supplement.

The specific objective of the program was to determine whether extended aeration activated sludge processes represented BPT for the treatment of dairy wastes and to provide a data base to be used in the development of regulations limiting the discharge of deleterious substances to the environment.

THE WASTEWATER TREATMENT SYSTEMS

Plant A

The wastewater from this plant was collected in four catch basins, each equipped with bar screens with openings of 2 cm. The wastewater was pumped to a 30 m^3 holding tank and flowed by gravity to a 675 m^3 oxidation ditch as shown in Figure 1. Aeration and mixing were provided by two cage rotors driven by a 15 and a 19 kW motor, respectively. Mixed liquor flowed by gravity to a

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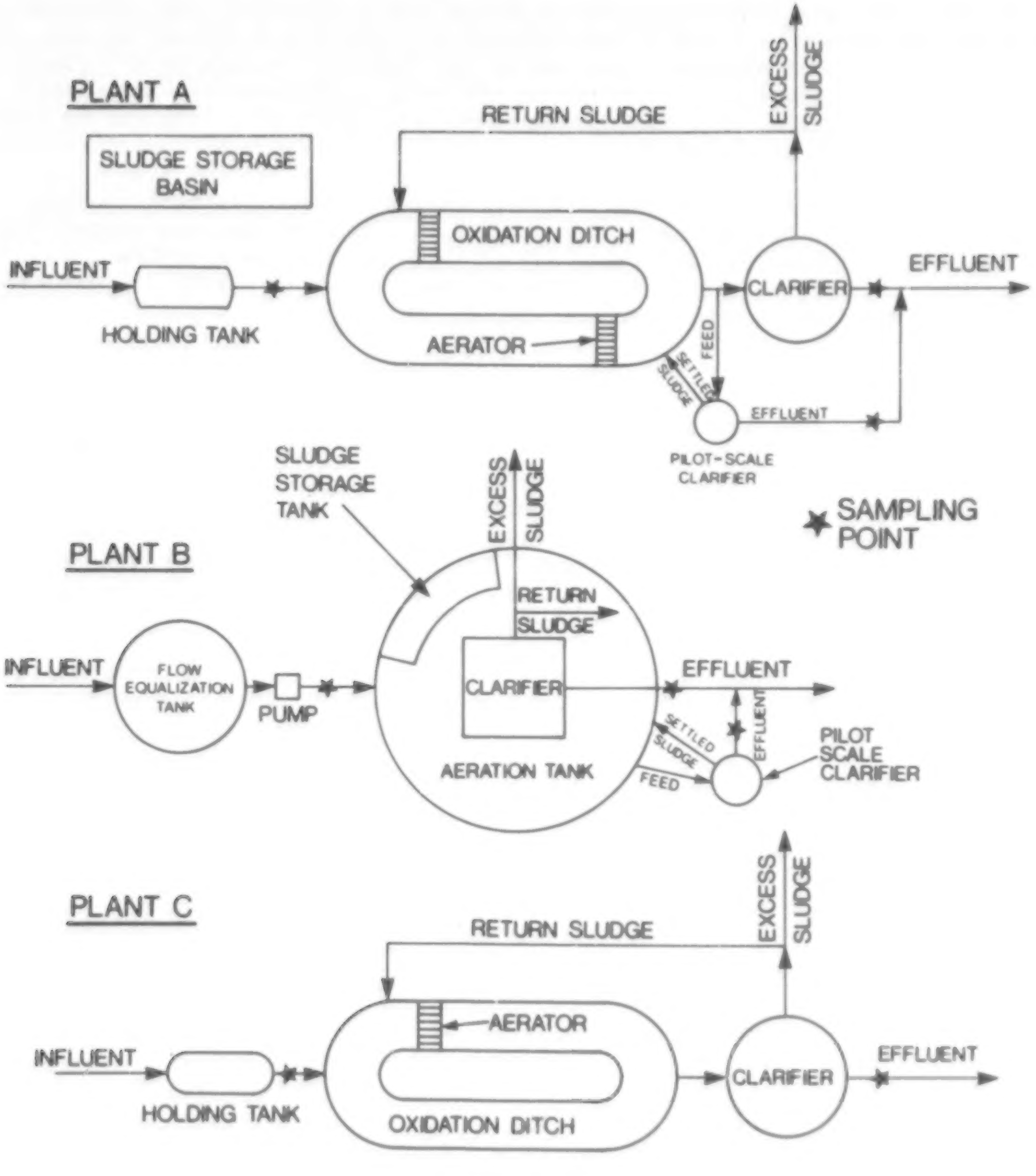

FIGURE 1. SCHEMATIC OF TREATMENT SYSTEMS

4.9 m diameter peripheral feed clarifier, having a volume of 89 m^3. Neither scum removing nor sludge scraping facilities were provided. The clarifier effluent was pumped to the municipal sewer system.

Before the study was initiated, settled sludge was returned to the oxidation ditch intermittently by a 1.8 m^3/min centrifugal pump which was set to operate 15 seconds every four minutes. Because of the hydraulic surges in the clarifier, this was changed to continuous operation at approximately 0.14 m^3/min. This mode of operation, providing a sludge recycle ratio of 1.2:1, was followed for the duration of the study.

Excess sludge was stored in a 675 m^3 sludge storage basin (Figure 1) during the winter months. During the summer operation, excess sludge was pumped from the clarifier and sprayed on a field adjacent to the treatment system. As sludge was not being stored in the basin at the time of the study, it was used to equalize the flow to the treatment system.

Plant B

Wastewaters requiring treatment were collected in a catch basin equipped with a 0.5 cm screen for separation of floating materials. The waste was pumped to a 225 m^3 flow equalization tank which was aerated by air diffusers. From the equalization tank, the waste was pumped at a constant rate to the aeration tank. The aeration tank having a capacity of 300 m^3, was the outer compartment of a 12.5 m diameter circular tank. The center compartment having a capacity of 68 m^3 was used as a clarifier. A schematic diagram of the treatment plant is presented in Figure 1.

Aeration and mixing in the aeration cell were provided by diffused air which was supplied by three 15 kW compressors located in a building adjacent to the treatment system.

Mixed liquor flowed by gravity to the 4.6 m by 4.6 m clarifier which was equipped with four sludge hoppers on the bottom. Settled sludge was recycled to the aeration tank by four air-lift pumps, one in each sludge hopper. In the original design, 100 mm diameter pipes were used in the air-lift pumps providing a return sludge flow approximately 600% of the plant influent. Shortly before the program was initiated, two of the pipes were reduced to 50 mm in diameter and the other two were replaced by 38 mm diameter pipes. These modifications decreased the return sludge rate from 600 to 200% of the plant influent.

The clarifier was equipped with a scum baffle at its perimeter to prevent floating solids from discharging with the effluent. The floating solids were collected in a pipe with a flared opening located at the center of the clarifier. An air-lift pump delivered the floating solids thus collected to the aeration tank. Effluent from the clarifier flowed by gravity to a creek. Excess sludge was sprayed as necessary on a field adjacent to the treatment system.

Plant C

The design of the treatment system at plant C was similar to that of plant A. The wastewater was pumped from a catch basin in the dairy plant to a 23 m^3 holding tank and then flowed by gravity to the 495 m^3 oxidation ditch as shown in Figure 1. Aeration and mixing were provided by a cage rotor driven by a 19 kW electric motor.

Mixed liquor flowed by gravity to a 4.3 m diameter peripheral feed clarifier with the surface area and volume being 14.5 m^2 and 58.5 m^3, respectively. Neither scum removal nor sludge scraping equipment was provided in the clarifier. Settled sludge was returned to the ditch by a 0.45 m^3/min pump which was operated by a timer to control the sludge recycle ratio at 40 to 250% of the plant influent. The excess sludge was sprayed on the field adjacent to the treatment system. The clarifier was housed in a building to prevent freezing in winter. The effluent from this plant was discharged to a river.

Pilot-Scale Clarifier

It was originally identified that there were solid-liquid separation problems with the clarifiers at plants A and B. Two pilot-scale clarifiers were installed and operated in parallel with the existing full-scale clarifiers. The pilot-scale clarifiers had an 80 cm diameter and a settling volume of 0.6 m^3. They were fed with the mixed liquor from the aeration basin at a constant flow rate. Settled sludge from both pilot-scale clarifiers was pumped to the aeration cells at 50-80% of the feed rate. Although sludge scraping mechanisms were provided in both clarifiers, they were not equipped with scum removal facilities.

MATERIALS AND METHODS

Monitoring Program

1. Collection four days per week of flow-proportioned, refrigerated, 24-hour composite samples of plant influent and effluent. These were analyzed for the biochemical oxygen demand (BOD_5), suspended solids and pH;

2. Twice weekly collection of effluent samples for fish toxicity (Samples were collected from the pilot-scale clarifiers at plants A and B and from the full-scale clarifier at plant C);

3. Daily measurement of temperature, dissolved oxygen, suspended solids and pH of the mixed liquor; and

4. Continuous measurement and recording of the flow rate to the treatment system.

Bioassay Testing

Static with replacement bioassays were carried out in the study. The undiluted effluent sample was cooled to 15°C and then sub-divided into four, 40-liter samples each held in polyethylene containers lined with disposable food and drug approved polyethylene bags. Ten juvenile rainbow trout (Salmo gairdneri) weighing between 1.5-2.0 g and averaging 4 to 5 cm in length were placed in one of the 40-liter samples for the first 24 hours, then transferred to the second, third and fourth containers after 24, 48 and 72 hours, respectively. Renewing the solutions every 24 hours provided an effluent volume to fish weight ratio of 2 ℓ/g·d. Dissolved oxygen concentrations in the effluent were maintained above 7.0 mg/ℓ by aerating the test solutions at 5 mℓ/ℓ·min. Solutions not containing fish were not aerated until a few hours prior to transferring the fish.

WASTEWATER FLOW AND CHARACTERISTICS

The flow rate and characteristics of wastes generated from each dairy plant were different, depending on the quantity of milk and type of products being processed. The degree of in-plant management exercised at each plant to reduce the waste load accounted for the difference in the quantity and quality of the waste. A discussion of the flow rate and characteristics of wastes from each dairy plant is presented in the following sections.

Wastewater Flow

The flow rate to the treatment system at plant A ranged from 59 to 255 m^3/d (Figure 2). During the first week of the study, no effort was made to control the flow to the treatment system and the daily flow rate fluctuated significantly. In the second week, part of the waste was diverted to the spraying field to reduce the hydraulic loading to the clarifier. Starting June 17, the waste from the dairy plant was stored in the sludge storage basin and a submersible pump delivered the waste at a constant rate to the oxidation ditch.

Approximately one week later, odour problems were encountered in the basin. Consequently, the daily flow rate to the treatment system was gradually increased in an attempt to empty the basin. At the same time, efforts were made to provide aeration and mixing to control the odour problems. During the period from June 17 to July 8, although the total flow to the treatment system changed from day to day, the flow rate was kept constant during individual days. On July 8, the basin was completely emptied and thoroughly cleaned. After July 8, the treatment system was operated at a flow rate which was approximately equal to the total daily flow from the dairy plant. This mode of operation allowed the sludge storage basin used for flow equalization to be emptied daily and prevented the septic condition from occurring in the basin.

Daily flow rate to the treatment system at plant B varied from 14 to 203 m^3/d with the average being 113 m^3/d (Figure 2). Daily adjustment of the flow rate was necessary in order to accommodate the flow variation coming from the dairy plant, however, the flow rate to the treatment system was kept constant during the individual days.

To promote mixing and oxygen transfer, the water depth in the flow equalization tank was maintained at greater than 0.6 m at all times. On June 28, the tank was emptied for cleaning. The discharge of the daily waste flow

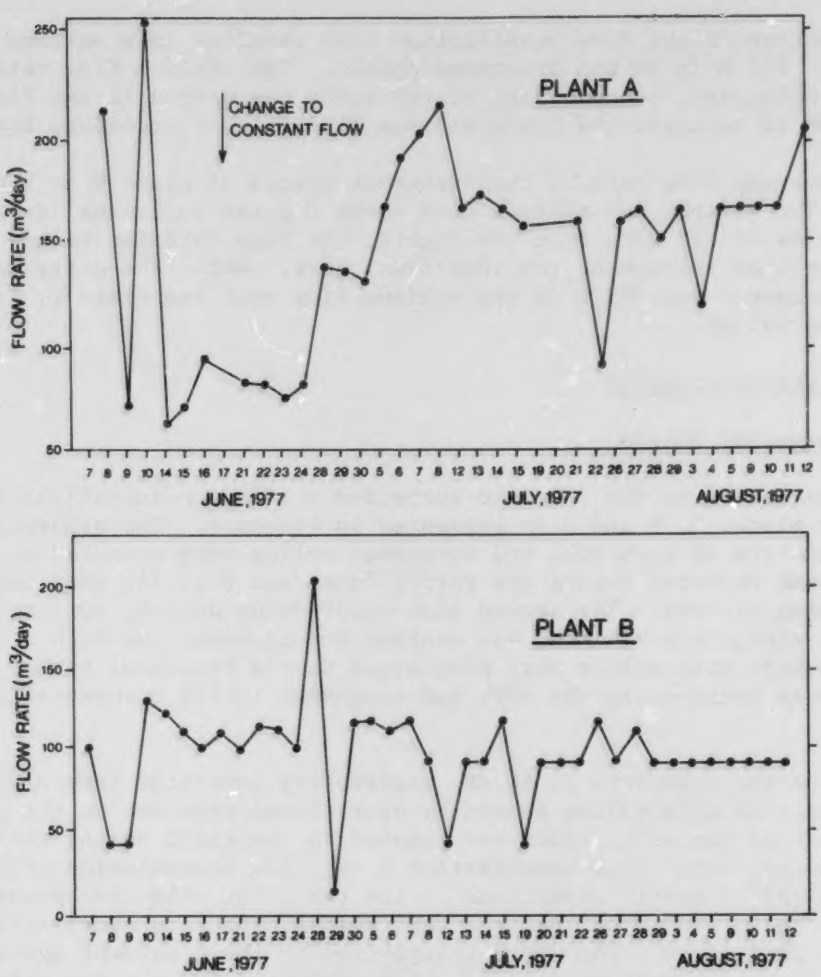

FIGURE 2. DAILY WASTE FLOWS TO THE TREATMENT SYSTEMS AT PLANTS A AND B

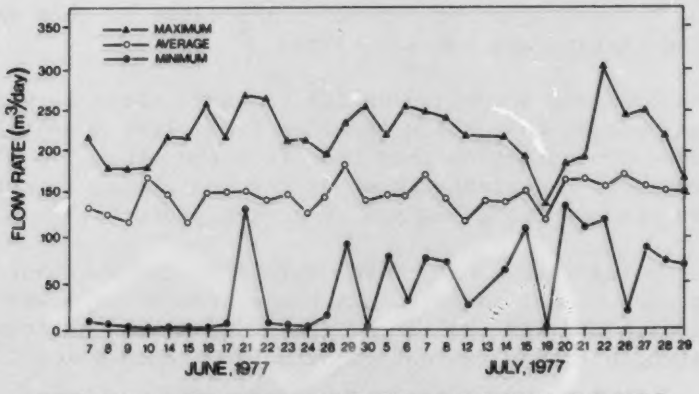

FIGURE 3. DAILY WASTE FLOWS TO THE TREATMENT SYSTEM AT PLANT C

plus the content of the flow equalization tank resulted in a maximum daily flow rate of 203 m^3/d to the treatment system. The minimum flow rate occurred on the following day, because part of the waste was stored in the flow equalization tank to maintain the 0.6 m minimum liquid level necessary for aeration.

The daily average flow rate to the treatment system at plant C is shown in Figure 3. The maximum and minimum flow rates for the individual days are also presented. As can be seen from the figure, the flow rate fluctuated from day to day as well as throughout the individual days. While the daily maximum flow rate measured was 295 m^3/d the minimum flow rate was close to zero on a number of occasions.

Wastewater Characteristics

BOD5 and Suspended Solids

The daily variation in the BOD_5 and suspended solids concentrations for the wastes from plants A, B and C is presented in Figure 4. Two abnormal peaks in the concentration of both BOD_5 and suspended solids were measured at plant A. The first peak occurred during the period from June 9 to 14, when the holding tank was being cleaned. The second peak occurred on July 8, corresponding to the day the sludge storage pond was emptied and cleaned. On both occasions, wastes with high milk solids were discharged to the treatment system, resulting in a great increase in the BOD_5 and suspended solids concentrations in the influent.

During the period from June 25 to 28, wastewaters generated from plant B were extremely high in milk solids caused by operational problems in the plant. Although part of the milk solids was removed in the catch basin, the majority were discharged to the flow equalization tank. The accumulation of milk solids resulted in septic conditions in the tank. As offensive odours were detected in the vicinity of the treatment system, the flow equalization tank was emptied on June 28. The waste transferred to the treatment system was septic and high in suspended solids, which accounted for the exceptionally high BOD_5 and suspended solids concentrations in the influent (Figure 4).

As shown in Figure 4, the waste from plant C exhibited a high peak in the suspended solids concentration on July 22. The cause of this exceptionally high solids concentration was not identified.

A summary of the BOD_5 and suspended solids concentrations is presented in Table 1. It can be seen that the wastewater from plant A contained a significantly higher BOD_5 concentration than that from the other two plants. This could be attributed to the discharge of wastes containing sugar which was used at this plant to produce ice cream and other ice products.

Analytical results indicated that there was sufficient phosphorus in the wastewater from each plant, however, the waste from plant A was deficient in nitrogen and aqueous ammonia (20% as N) was added to the untreated waste. A supplemental nitrogen source was not required at plants B and C.

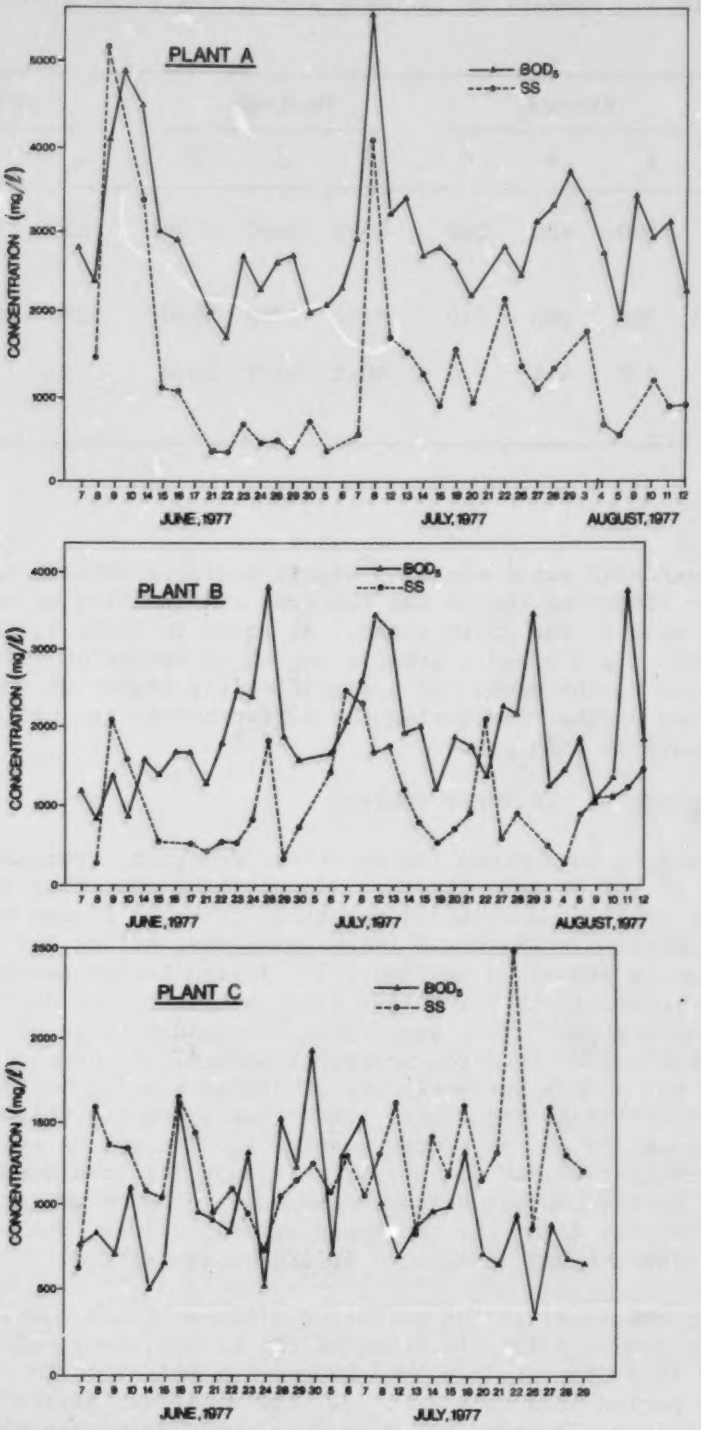

FIGURE 4. DAILY INFLUENT BOD$_5$ AND SUSPENDED SOLIDS CONCENTRATIONS

TABLE 1. SUMMARY OF INFLUENT WASTEWATER CHARACTERISTICS

Parameters	Minimum			Maximum			Average		
	A	B	C	A	B	C	A	B	C
BOD_5 (mg/ℓ)	1700	840	380	6000	3800	1900	2850	1960	950
Suspended Solids (mg/ℓ)	350	300	610	5190	2460	2500	1290	1120	1240
pH	3.8	4.4	7.2	10.1	10.9	12.0	-	-	-

pH

The pH of the untreated waste was also highly variable for all the plants. The major factor affecting the pH was the type and quantity of sanitizers and cleaning agents used in the dairy plant. As shown in Table 1, the pH of the wastes from plants A and B had a greater degree of variation than that from plant C. At plant C, the waste had a significantly higher pH value than that from the other two plants, indicating the difference in the use of sanitizers and cleaning agents at this plant.

OPERATING PARAMETERS OF TREATMENT SYSTEMS

The average operating parameters for the three treatment systems are shown in Table 2. Based on the organic loadings, it could be seen that all three systems were operated as an extended aeration activated sludge process. The day to day fluctuation in the mixed liquor suspended solids for the three treatment systems is presented in Figure 5. A significant increase in MLSS concentration occurred in the oxidation ditch at plant A on July 8, when the storage basin was emptied. This was caused by the discharge of a high concentration of milk solids into the treatment system. Although efforts were made to control the solids concentration by sludge wasting on the following days, it was impossible to reduce the concentration to its original level due to the limited capacity of the sludge wasting facilities. A steady decrease in the MLSS concentration did not occur until July 22; two weeks after the increase in the solids concentration. Apparently, the amount of sludge wasted during this period was offset by the rapid solids build-up due to microbial growth and the high influent suspended solids concentration.

The dissolved oxygen level in the oxidation ditch at plant A was generally maintained above 2 mg/ℓ. The discharge of the high concentration of milk solids resulted in a drop of dissolved oxygen concentration to less than 0.5 mg/ℓ during the period from July 8 to 13. Low dissolved oxygen levels measured on July 5 and 29 were caused by a malfunction of one surface aerator.

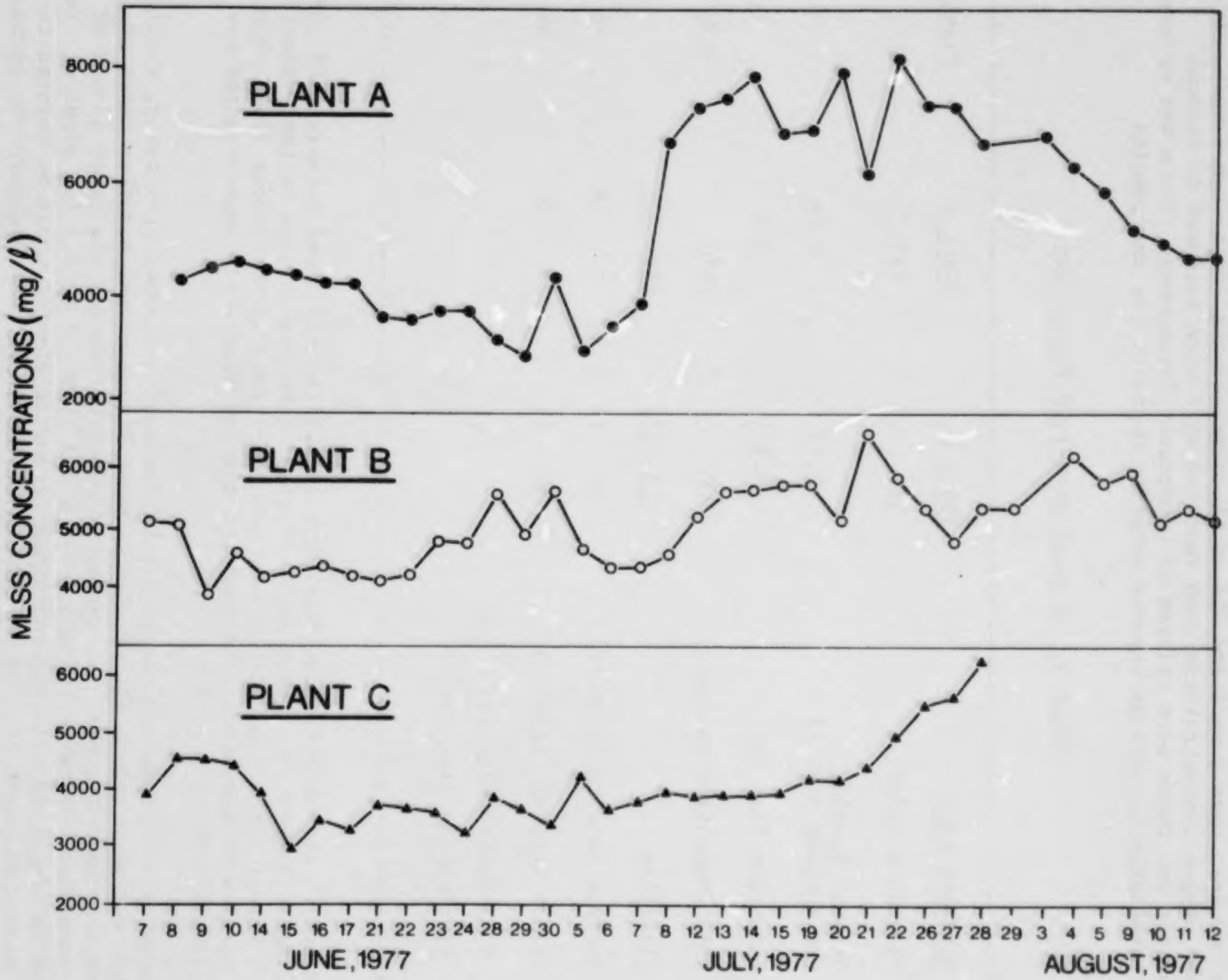

FIGURE 5. MIXED LIQUOR SUSPENDED SOLIDS CONCENTRATIONS

The MLSS concentration in the aeration tank at plant B was maintained between 3900 and 6600 mg/ℓ (Figure 5). Although the three compressors were operated at full capacity, 50% of the time, the dissolved oxygen level in the aeration tank was less than 1 mg/ℓ and 75% of the time, it was lower than 2 mg/ℓ. Dissolved oxygen concentrations less than 0.5 mg/ℓ were measured on several occasions and these were related to compressor breakdowns. There was no spare unit available to provide reserve aeration capacity for emergencies.

TABLE 2. AVERAGE OPERATING PARAMETERS

1. Aeration Tank	Plant A		Plant B		Plant C
Flow Rate (m^3/d)	142		113		170
Organic Loading (kg BOD_5/kg MLSS·d)	0.11		0.14		0.08
Detention Time (d)	4.8		2.7		2.9
MLSS Concentration (mg/ℓ)	5300		5070		4030
2. Clarifier	(1)	(2)	(1)	(2)	
Surface Loading ($m^3/m^2 \cdot d$)	10	14	5	14	16
Solids Loading ($kg/m^2 \cdot d$)	44	49	24	65	54

(1) Full-Scale Clarifier

(2) Pilot-Scale Clarifier

At plant C, the MLSS concentration was generally maintained between 3500 and 4500 mg/ℓ (Figure 5). There was sufficient dissolved oxygen in the oxidation ditch except for two occasions when extremely low concentrations (less than 0.5 mg/ℓ) were measured. The cause of the low dissolved oxygen reading was not identified.

Although the influent pH was highly variable as mentioned previously, little change was observed in the pH of the mixed liquor in the aeration tanks of all three treatment systems. It ranged from 6.9 to 7.9 for the mixed liquor of the treatment systems at plants A and B and from 7.4 to 8.8 for plant C. The slightly higher pH value of the mixed liquor at plant C could be related to the higher influent pH. As all the mixed liquor pH's were within the optimum range for microbial growth in a biological treatment system, there was no requirement for chemical addition for pH adjustment. It must be concluded that there was always sufficient mixing and buffering capacity in the aeration tank to neutralize the waste.

The surface and solids loadings of the full- and pilot-scale clarifiers are shown in Table 2. The loadings shown for the pilot-scale clarifiers were calculated based on a flow rate of 4.6 ℓ/min.

OPERATING RESULTS

Plant A

The daily effluent BOD_5 and suspended solids concentrations for both the pilot- and full-scale clarifiers are shown in Figure 6 and 7, respectively. As can be seen from the figures, the pilot-scale clarifier operated at a constant flow rate produced significantly better quality effluent during the first month of operation. After the operational problems in the full-scale clarifier were rectified by flow equalization, a stable operation was achieved. Starting July 6, the quality of effluents from both clarifiers was comparable.

The deterioration in the effluent quality of the pilot-scale clarifier on July 13 and 14, could be related to the high solids concentration in the oxidation ditch caused by the discharge of milk solids. The significant increase in the MLSS concentration after July 8, resulted in an increase in solids loading from 49 to 88 $kg/m^2 \cdot d$ which was too high for the pilot-scale clarifier. The sludge blanket was at the top of the clarifier on both days. To rectify the problem, the feed rate was reduced from 4.6 to 3.2 ℓ/min on July 15 which resulted in a reduction of the solids loading from 88 to 63 $kg/m^2 \cdot d$ and the surface loading from 14 to 10 $m^3/m^2 \cdot d$. As a result, the sludge blanket dropped and good quality effluents were achieved for the rest of the study.

The average BOD_5 and suspended solids concentrations for effluents from the pilot-scale clarifier were 12 and 43 mg/ℓ, respectively, which corresponded to a 99% BOD_5 and 97% suspended solids reduction. These results were calculated using all the collected data except those on July 13 and 14.

Effluent data from the full-scale clarifier could be divided into two groups. One group dealt with the data collected prior to July 5, which covered the first five weeks of operation. BOD_5 and suspended solids concentrations during this period of operation were extremely high and exhibited a great degree of fluctuation. The other group represented the data obtained after July 6, when the daily waste flow to the treatment system was kept constant. This group of data collected over a period of approximately six weeks represented the performance of a well designed and properly operated treatment system and was considered to be representative of the BPT operation. A summary of the operating results for this group is shown in Table 3.

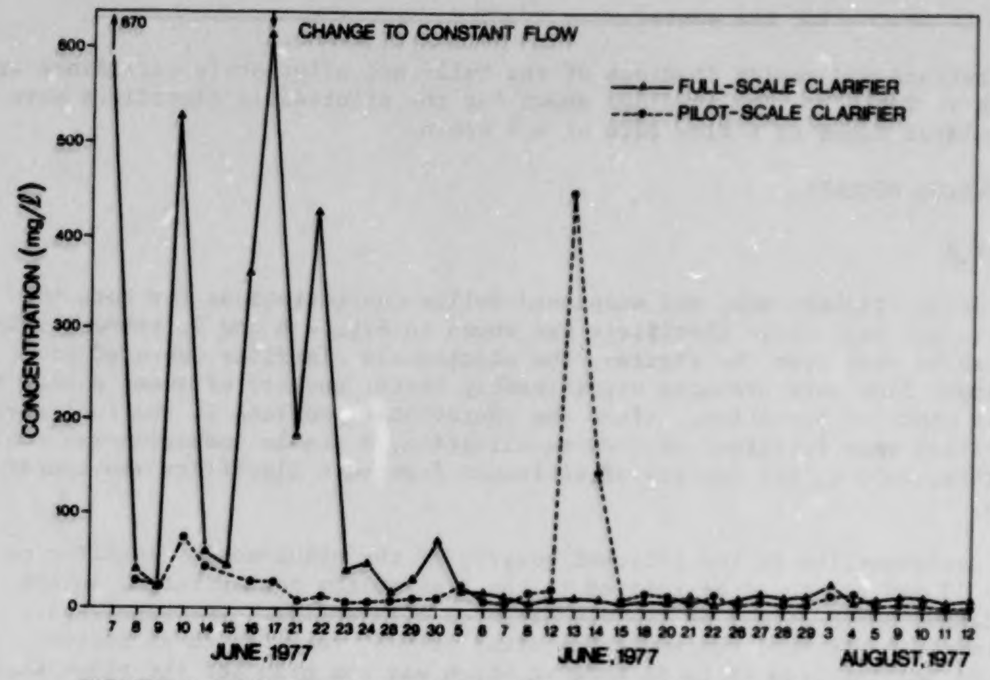

FIGURE 6. DAILY EFFLUENT BOD_5 CONCENTRATIONS AT PLANT A

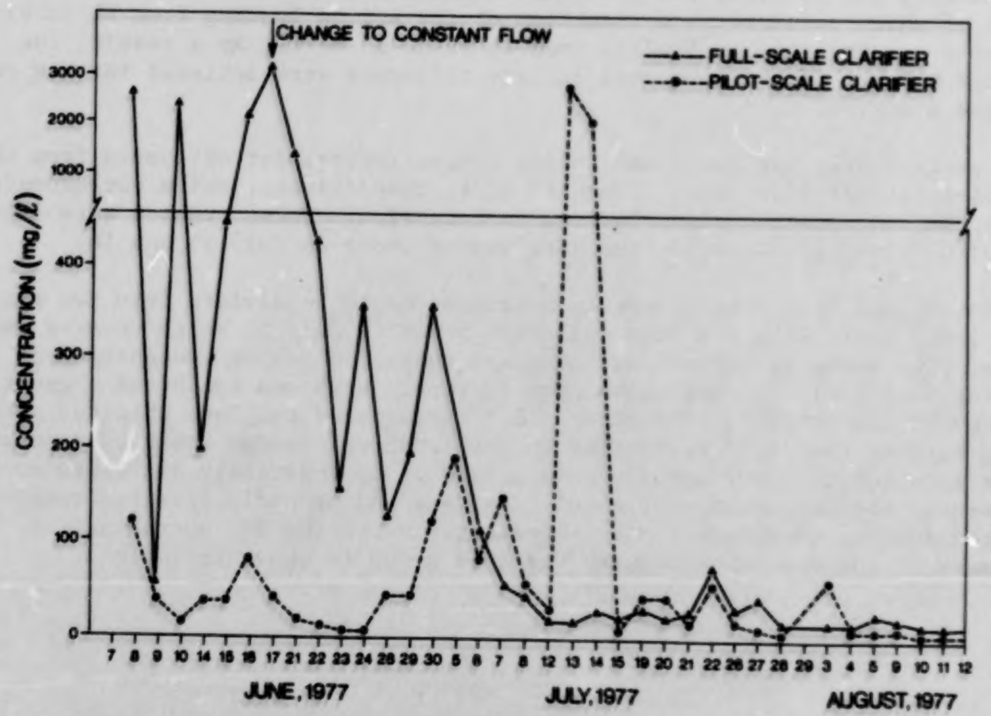

FIGURE 7. DAILY EFFLUENT SUSPENDED SOLIDS CONCENTRATIONS AT PLANT A

TABLE 3. SUMMARY OF EFFLUENT RESULTS - PLANT A, FULL-SCALE CLARIFIER*

Parameters	Minimum	Maximum	Average	% Reduction
BOD_5 (mg/ℓ)	7	29	13	99
Suspended Solids (mg/ℓ)	12	109	32	98

* Data collected from July 6 to August 12, 1977

From the data presented, it can be seen that the performance of the treatment system was significantly improved by flow equalization. Before June 17, the sludge blanket in the clarifier was visible at all times and on several occasions it reached the water surface resulting in severe loss of sludge over the weir of the clarifier. Starting June 17, when the sludge storage basin was used to equalize the flow, the sludge blanket gradually dropped in the clarifier. Approximately one week later, the sludge blanket was no longer visible.

During the operating period from June 24 to July 7, scum was observed in both clarifiers. The scum was formed in the oxidation ditch and was carried over to the clarifier with the mixed liquor. As neither the full-scale nor the pilot-scale clarifier was equipped with scum removal facilities, the solids were carried away with the effluent resulting in a high suspended solids concentration in effluents from both clarifiers (Figure 7). However, the BOD_5 results were only slightly affected by the scum in the sample as shown in Figure 6. This indicated that most solids in the scum were inert and did not exert an oxygen demand.

A malfunction of the effluent pump caused by power failure on June 30, resulted in a rise of the water level and sludge blanket in the full-scale clarifier. The high sludge blanket, in addition to the scum problem mentioned earlier, could have been partially responsible for the high effluent BOD_5 and suspended solids concentrations measured.

After July 6, stable operation of the treatment system was achieved. The discharge of 210 m^3 of highly concentrated wastes to the oxidation ditch on July 8, appeared to have no affect on the performance of the treatment system.

As indicated before, aqueous ammonia was added to the waste as a supplemental nitrogen source. During the first two weeks of operation, ammonia was added at 200 mg/ℓ in terms of nitrogen. This dosage was based on an estimated influent BOD_5 concentration of 4000 mg/ℓ. As excessive ammonia concentrations in the effluent samples were detected, the dosage was reduced to 114 mg/ℓ on June 16. Although the effluent ammonia concentration started to decrease, a steady increase in the nitrite concentration was observed in effluents from both clarifiers. Apparently the ammonia dosage was still too high and the decrease in the effluent ammonia concentration after the reduced dosage was partially attributed to nitrification occurring in the system. On July 4, the ammonia dosage was reduced again to 58 mg/ℓ. Two days later, a steady decrease in the nitrite concentration was measured in the effluent. After July 13, both the ammonia and nitrite concentrations in the effluent were consistently less than 1 mg/ℓ expressed as nitrogen.

During the period when high nitrite concentrations were measured in the effluent, no nitrate was detectable, indicating that nitrification was not complete. The cause of this phenomenon was not investigated during the study.

Plant B

The daily BOD_5 concentration of effluents from both the full- and pilot-scale clarifiers is shown in Figure 8. The effluent suspended solids data are presented in Figure 9. As can be seen from Figure 8, the BOD_5 results from both clarifiers were comparable. The discharge of a highly concentrated waste, combined with the extremely high flow rate on June 28, detrimentally affected the performance of the treatment system. A substantial increase in the population of filamentous micro-organisms was observed in the sludge floc and the sludge blanket in both clarifiers reached the water surface during the period from June 28 to July 6. The continuous loss of sludge over the clarifiers resulted in a deterioration of the effluent quality as shown in Figures 8 and 9.

Scum, similar to that occurring in the treatment system at plant A, was frequently observed in both clarifiers. As the full-scale clarifier was equipped with baffle and skimming devices, the scum, if not too excessive, could be prevented from discharging with the effluent. However, such facilities were not available in the pilot-scale clarifier. As a result, effluents from the pilot-scale clarifier usually contained higher suspended solids than those from the full-scale clarifier.

Aside from the period between June 28 and July 6, suspended solids concentrations greater than 100 mg/ℓ were measured in the effluent from the full-scale clarifier on four occasions. This was attributed to an excessive scum accumulation in the clarifier, resulting in partial discharge of solids with the effluent.

Rising bubbles and lumps of black sludge were observed in the full-scale clarifier on several occasions. As the clarifier was not equipped with sludge scraping mechanisms, this allowed part of the sludge to adhere to the bottom of the clarifier. Prolonged storage of sludge resulted in denitrification or the development of septic conditions which caused the sludge to rise to the surface. Because the clarifier was equipped with scum baffle, the floating sludge was retained in the clarifier and prevented from leaving with the effluent. Eventually the floating sludge either sank to the bottom or was collected by the skimming device and returned to the aeration tank by an air-lift pump. This problem was not encountered in the pilot-scale clarifier as it was equipped with sludge scraping facilities.

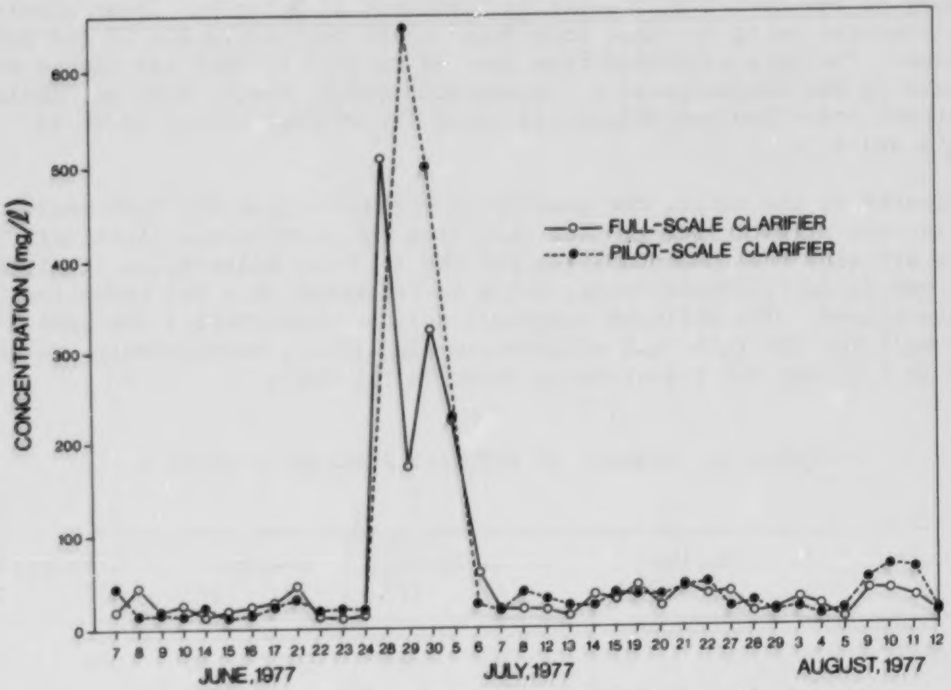

FIGURE 8. DAILY EFFLUENT BOD$_5$ CONCENTRATIONS AT PLANT B

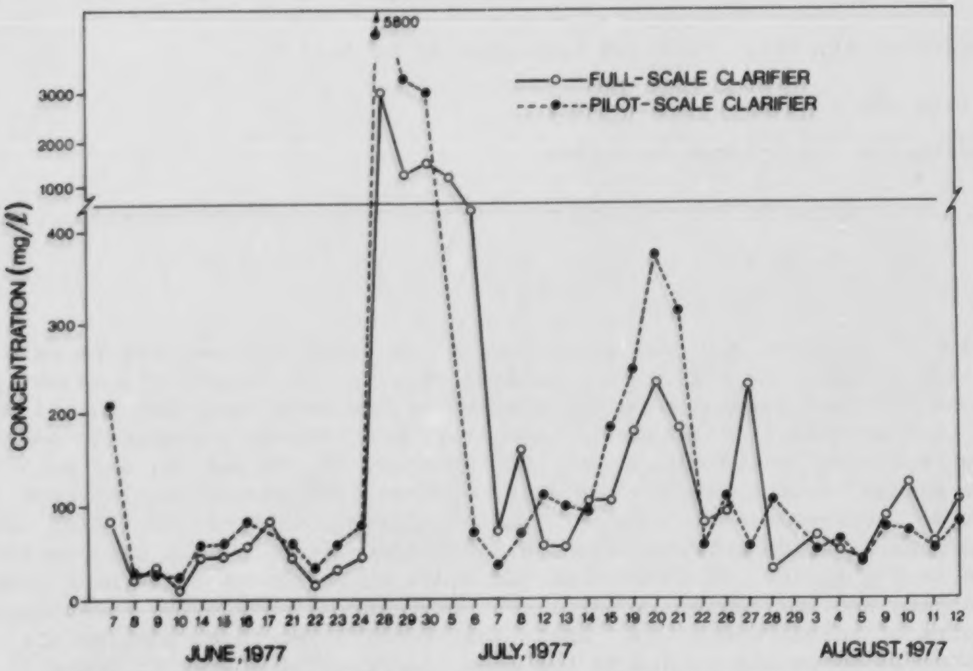

FIGURE 9. DAILY EFFLUENT SUSPENDED SOLIDS CONCENTRATIONS AT PLANT B

A summary of the operating results is presented in Table 4. These results were calculated using the data considered to be representative of the BPT operation. The data collected from June 28 to July 6, when the system was upset due to the discharge of a concentrated septic waste, were not included. The percent reduction was calculated using the average values shown in Tables 1 and 4.

As indicated in the table, the quality of effluents from the full-scale clarifier was slightly better than that from the pilot-scale clarifier. The average effluent BOD_5 concentration for the full-and pilot-scale clarifiers was 22 and 25 mg/ℓ, respectively, which corresponded to a 99% reduction for both clarifiers. The effluent suspended solids concentration averaged 55 and 65 mg/ℓ for the full- and pilot-scale clarifiers, respectively, which resulted in a 95 and 94% reduction as shown in the table.

TABLE 4. SUMMARY OF EFFLUENT RESULTS* - PLANT B

Parameters	Minimum (1)	Minimum (2)	Maximum (1)	Maximum (2)	Average (1)	Average (2)	% Reduction (1)	% Reduction (2)
BOD_5 (mg/ℓ)	3	7	50	63	22	25	99	99
Suspended Solids (mg/ℓ)	9	24	250	368	55	65	95	94

* Excluding the data collected from June 28 to July 6.

(1) From the full-scale clarifier

(2) From the pilot-scale clarifier

Plant C

The plot of effluent BOD_5 and suspended solids concentrations versus date of operation is shown in Figure 10. As indicated in the figure, the majority of effluent BOD_5 and suspended solids concentrations were less than 20 and 50 mg/ℓ, respectively. Occasionally, temporary problems with hydraulic surges were encountered in the clarifier. On June 14, 24, 29 and 30, and July 5 and 7, the sludge blanket reached the water surface for periods ranging from 2 to 12 hours, causing loss of solids in the clarifier. The resultant high BOD_5 and suspended solids concentrations are encircled and shown as unconnected points in Figure 10. On these days, in addition to the usual 24-hour composite sample, another composite sample was prepared using samples taken during the hours of normal operation. Analytical results for these samples are presented as connected points in the same figure. The number of hours of normal operation varied from 12 to 22 hours and has been noted in the figure.

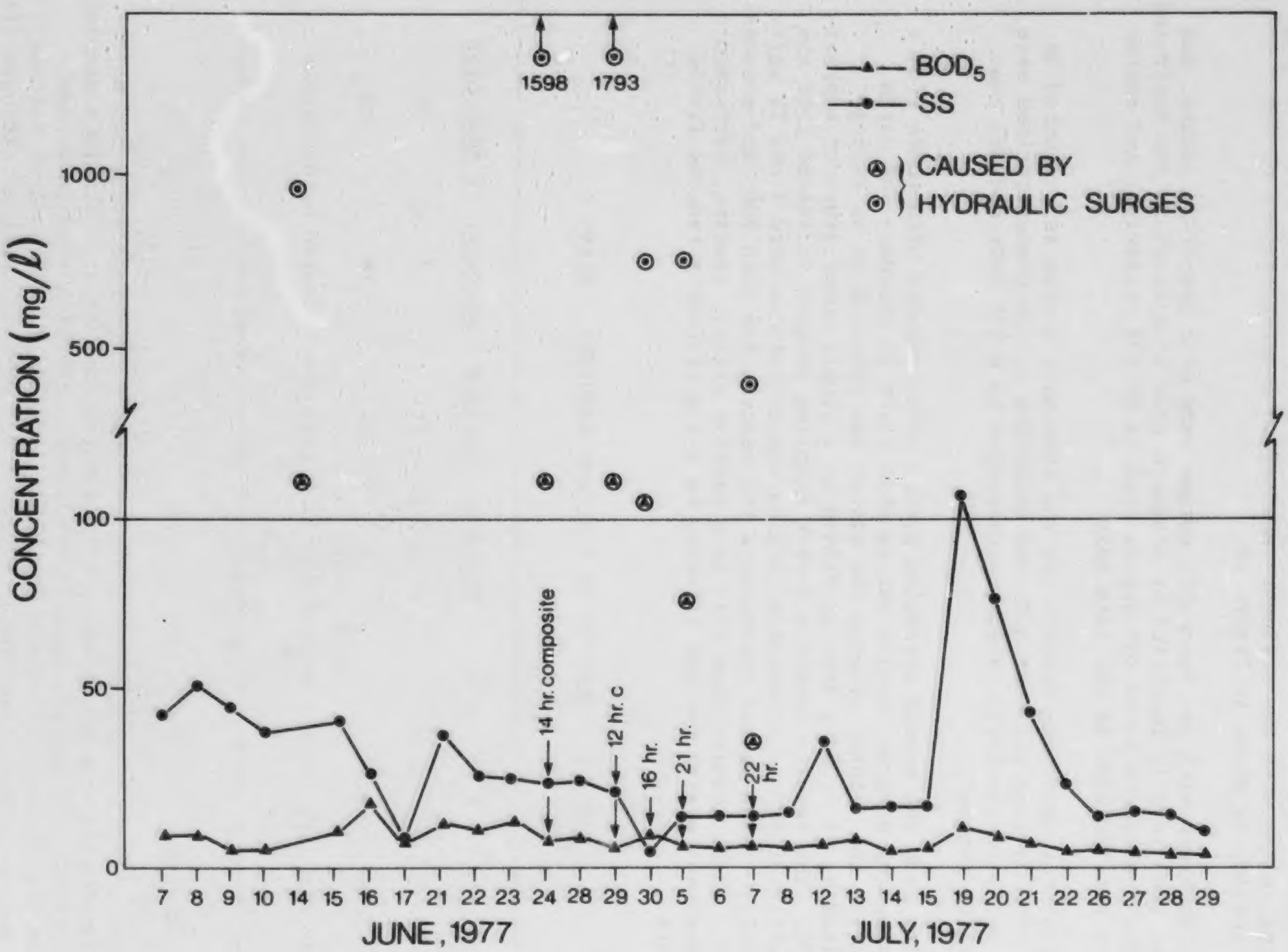

FIGURE 10. DAILY EFFLUENT BOD$_5$ AND SUSPENDED SOLIDS CONCENTRATIONS AT PLANT C

During the week of July 19 to 22, floating sludge was observed in the clarifier. The problem could be attributed to nitrification or the development of septic conditions in the clarifier as mentioned previously. The discharge of floating solids with the effluent resulted in a deterioration of the effluent quality as shown in Figure 10.

Since the problems with the hydraulic surges were of a temporary nature, and could have been readily rectified by adequate flow equalization, the encircled values were considered to be not representative of BPT operation, and therefore, were not included in the data anlysis.

A summary of the operating results for the treatment system is presented in Table 5. The average effluent BOD_5 and suspended solids concentrations were 7 and 28 mg/ℓ, respectively, which corresponded to a 99% BOD_5 and 98% suspended solids removal.

The results from the summer operating period were compared with those from a similar sampling program carried out at this plant in February and March 1976. During the winter program the system was operated at an average organic loading of 0.09 kg BOD_5/kg MLSS·d at a liquid temperature of approximately 8°C. The results from the 5-week sampling program indicated that the average effluent BOD_5 and suspended solids concentrations were 7 and 12 mg/ℓ, respectively; these values represent a 99% removal for both BOD_5 and suspended solids. These results show that at a similar organic loading, performance of the treatment system was not affected by a significantly reduced liquid temperature.

TABLE 5. SUMMARY OF EFFLUENT RESULTS* - PLANT C

Parameters	Minimum	Maximum	Average	% Reduction
BOD_5 (mg/ℓ)	2	18	7	99
Suspended Solids (mg/ℓ)	5	49	28	98

*Excluding the data collected when the clarifier was affected by hydraulic surges

BIOASSAY RESULTS

The results of fish bioassays are shown in Table 6. As indicated, the majority of the samples were non-acutely lethal to rainbow trout. The four samples which exhibited 100% mortality, were associated with high ammonia concentrations in the effluent. Ammonia has been reported to be lethal to rainbow trout in the un-ionized form (NH_3) at 0.2 to 0.5 mg/ℓ in terms of nitrogen (1). Analytical results indicated that the samples exhibiting 100% fish mortality contained 0.7 to 2.9 mg/ℓ of non-ionized ammonia expressed as nitrogen. The high ammonia concentration present in the effluent from the treatment system at plant A was due to an over-dosage of ammonia in the waste as indicated previously. No explanation could be provided for the high ammonia concentration in the effluents from the treatment systems at plants B and C.

TABLE 6. BIOASSAY RESULTS

Plant	No. of Samples Tested	No. of Samples Exhibiting No Mortality	Remarks
A	15	11	1 sample exhibited 100% mortality 1 sample exhibited 20% mortality 2 samples exhibited 10% mortality
B	17	15	Both samples exhibited 100% mortality
C	15	14	100% mortality

As mentioned previously, over-dosage of ammonia during the early weeks of the study also resulted in a high nitrite concentration in the effluent. Analytical results indicated that the three samples from plant A exhibiting partial mortality contained 36 to 96 mg/ℓ of nitrite-nitrogen which were 150 to 400 times the lethal level of 0.23 mg/ℓ reported by Brown and McLeay (2). However, only 10 to 20% mortality was observed, suggesting that some form of antagonism was occurring in the sample. Perrone and Meade (3) reported a positive interaction between nitrite and chloride. Subsequent analyses of the effluents revealed chloride levels of 200 to 500 mg/ℓ. The antagonistic relationship was confirmed by exposing rainbow trout to 50 mg/ℓ of nitrite-nitrogen with and without 300 mg/ℓ of chloride. The samples containing chloride were non-acutely lethal while samples without chloride resulted in 100% mortality.

OPERATIONAL PROBLEMS AND CORRECTIVE MEASURES

Three major operational problems were encountered at the treatment systems during the study. The nature of the problems and their corrective measures are presented as follows:

Hydraulic Surges

Hydraulic surges to the treatment system caused by washing and cleaning operations in the dairy plant have resulted in overloading of the clarifiers at plants A and C. The hydraulic surges lifted the sludge blanket to the surface of the clarifier, resulting in a discharge of suspended solids. The solution to the problem was to provide a constant flow to the treatment system which can be accomplished by the use of a flow equalization tank. This can be provided through the construction of new facilities or through the modification of existing facilities. During the study the sludge storage basin at plant A was used for this purpose. However, it should be noted that the basin is not available for flow equalization in winter months as it is used to store the excess sludge from the treatment system. To ensure a satisfactory performance year-round, flow equalization is required.

At plant C, an attempt was made to determine the feasibility of using the existing holding tank to equalize the flow. The diurnal flow pattern of the day having the most variable flow during the study was selected (Figure 11) and a hydrograph was constructed as shown in Figure 12. The vertical distance between the two solid lines tangent to the accumulated flow curve represents the storage volume required. This volume was calculated to be 23 m^3 which happened to be the same as the volume of the holding tank on site. Therefore, it is feasible to operate the holding tank as a flow equalization tank to provide a constant flow to the oxidation ditch. The only modification required is to install a pump having the capacity to handle the average daily flow. As no reserve capacity is available, occasional overflow could occur due to unforseen changes in diurnal flow. The effect of such an overflow on the treatment system would be less significant than the effect of the unequalized hydraulic surges experienced during the study.

The problems with hydraulic surges did not occur at plant B, because a flow equalization tank was available at this plant.

Scum

During the study, the aeration tanks at plants A and B were covered with a thick scum sometimes to a depth of 0.5 m. It was called 'scum' rather than 'foam' because it could not be collapsed by water spraying. Part of the scum entered the clarifiers with the mixed liquor, resulting in floating solids in the clarifiers. As no scum removal facilities were available at plant A, the solids were carried over the weir of the clarifier, producing effluents with high suspended solids concentration. The scum in the clarifier at plant B was retained by the scum baffle and eventually was returned to the aeration tank by an air-lift pump or removed manually.

The solution to the problem is to control the scum formation, or failing this, to remove the scum from the oxidation ditch. Scum can be prevented from entering the clarifier with the mixed liquor by a properly designed entrance facility. As a final measure, scum baffle and skimming devices should be provided in the clarifier to keep the scum from discharging with the effluent.

Floating Sludge

Rising bubbles and lumps of black sludge were observed on several occasions, in each of the full-scale clarifiers. As none of the clarifiers were equipped with sludge scraping mechanisms, this allowed part of the sludge to adhere to the bottom of the clarifier. Prolonged storage of sludge resulted in denitrification or the development of septic conditions which caused the sludge to rise to the surface.

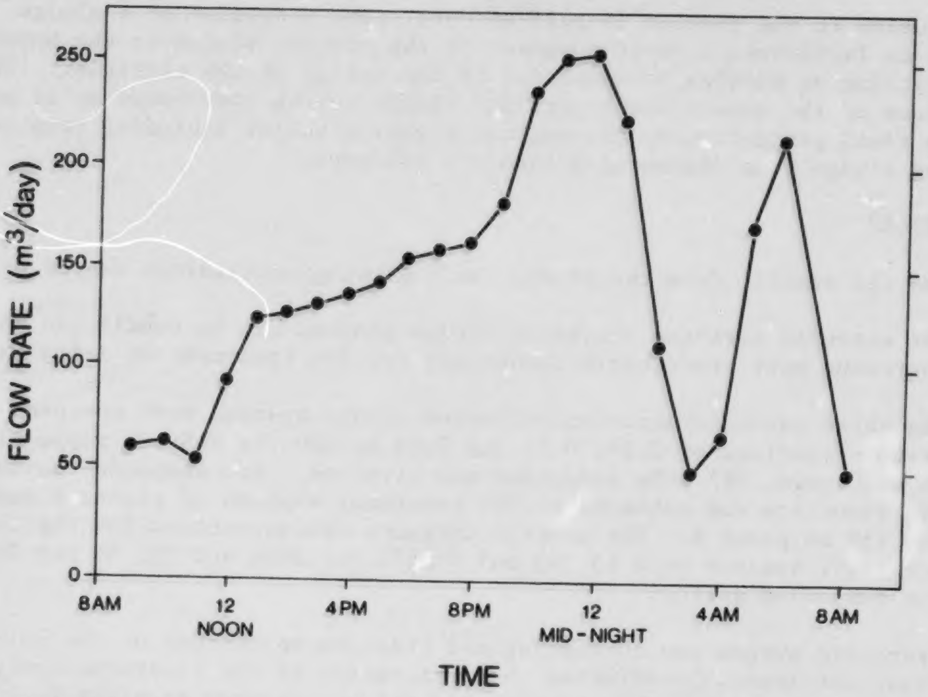

FIGURE 11. THE MOST VARIABLE DIURNAL FLOW PATTERN AT PLANT C

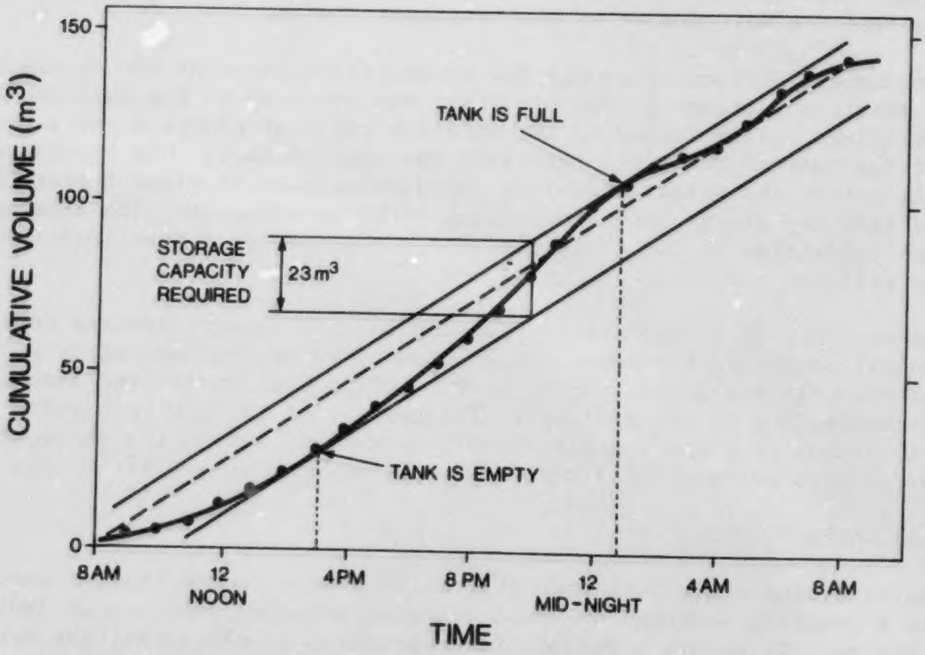

FIGURE 12. HYDROGRAPH FOR THE DIURNAL FLOW PATTERN PRESENTED IN FIGURE 11

The solution to the problem is self-evident. The provision of a sludge scraper to facilitate a rapid movement of the settled sludge to the hopper for recycling or wasting is essential in the design of the clarifier. The importance of the scum removal facility should not be overlooked as it provides a final protection to prevent the floating solids including scum and floating sludge from discharging with the effluent.

CONCLUSIONS

Based on the results from the study, the following conclusions can be drawn:

1. The extended aeration activated sludge process can be considered to represent best practicable technology for the treatment of dairy wastes.

2. The three extended aeration activated sludge systems were operated at organic loadings of 0.11, 0.14 and 0.08 kg BOD_5/kg MLSS·d, respectively. In each case, 99% BOD_5 reduction was attained. For suspended solids a 98% reduction was achieved at the treatment systems of plants A and C, and 95% at plant B. The average effluent concentrations for the three treatment systems were 13, 22 and 7 mg/ℓ for BOD_5 and 32, 55 and 28 mg/ℓ for suspended solids.

3. Hydraulic surges due to washing and cleaning operations of the dairy plant detrimentally affected the performance of the treatment systems at plants A and C. This problem was not encountered at plant B, because flow equalization facilities were available. The use of the existing sludge storage basin for flow equalization at plant A substantially improved the performance of the treatment system.

4. Occasionally, floating sludge due to denitrification or the development of septic conditions in the clarifier was observed in the full-scale clarifiers. Scum formed in the aeration cells at plants A and B was carried over to the clarifiers with the mixed liquor. The provision of scum baffle and skimming devices in the clarifier at plant B prevented the floating sludge from discharging with the effluent. The absence of such facilities in the other clarifiers resulted in a deterioration of the effluent quality.

5. The majority of the effluents from the three treatment systems were non-acutely lethal to rainbow trout. In cases where fish mortality was observed, it was identified to be related to high un-ionized ammonia concentrations in the effluent. Effluents containing high nitrite concentrations were not acutely lethal, presumably due to the antagonistic interaction between nitrite and chloride present in the effluents.

DESIGN RECOMMENDATIONS

The results of the study indicated that dairy wastes can be treated successfully in a properly designed and well operated extended aeration activated sludge system. To ensure a satisfactory operation at all times, the system should consist of the following components:

1. Catch basin equipped with screening devices to remove large floating materials.

2. Flow equalization tank to provide a constant flow to the subsequent treatment units.

3. Aeration tank to oxidize the organic compounds in the waste.

4. Clarifier to separate the biological solids from the liquid.

A supplemental nitrogen source will be required for treating the wastes which are deficient in this nutrient.

Based on the experience gained at the three systems, the following important parameters should be considered in the design of a treatment system.

For the flow equalization tank, the volume is determined, based on the diurnal flow pattern of the waste to be treated. Aeration and mixing should be provided to prevent septic conditions and to avoid deposition of solids in the tank. Design details on this subject are covered in an EPA report entitled "Flow Equalization" (4).

As an alternative, the use of the aeration tank to dampen the flow and a pump to provide a constant flow of mixed liquor to the clarifier may be a cost-effective solution for some treatment systems. However, the feasibility of using this mode of operation is dependent on the degree of flow variation and should be investigated on a case by case basis.

The aeration tank should be designed at an organic loading of approximately 0.1 kg BOD_5/kg MLSS·d. Sufficient aeration and mixing should be provided to maintain a dissolved oxygen level at greater than 1 mg/ℓ, preferably 2 mg/ℓ throughout the aeration tank. Efforts should be made to keep the MLSS concentration between 4000 and 6000 mg/ℓ.

The use of a completely mixed aeration cell is strongly recommended as it minimizes the effect of fluctuating pH levels in the dairy wastes and provides a well balanced system without additional pH adjustment. The requirement for a pH control facility is thus eliminated.

As the sludge floc produced from the system treating dairy wastes always contains filaments and is non-compact in nature, a conservative surface loading of less than 16 $m^3/m^2 \cdot d$ is recommended in the design of the clarifier. This was selected based on the loading used at plant C, which was the highest among the three treatment systems investigated. Higher loadings may be used if justified by experimental data on sludge settling characteristics. Sludge scraping mechanisms must be provided in the clarifier to facilitate a rapid movement of the settled sludge to the hopper for recycling or wasting. As indicated before, prolonged storage of settled sludge in the clarifier resulted in a significant deterioration of the effluent quality. It is, therefore, essential to operate the clarifier with as little sludge on the bottom as possible. The sludge recycling and wasting equipment should be provided with sufficient capacity to ensure prompt removal of settled sludge.

As scum is frequently formed in the aeration cell and carried over to the clarifier with the mixed liquor, the clarifier should also be equipped with baffle and skimming devices to prevent the scum and other floating solids such as rising sludge from discharging with the effluent.

Based on the performance data obtained from the three treatment systems investigated, a properly operated extended aeration activated sludge system, designed according to the above criteria should produce effluents containing less than 20 mg/ℓ of BOD_5 and 30 mg/ℓ of suspended solids.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the management and staff of the three dairy plants involved in the study. Special appreciation is expressed to Messrs. K. Conn and V.W. Cairns, Laboratory Services Section of the Wastewater Technology Centre (WTC) for carrying out chemical analyses and fish bioassays. The authors also wish to thank Mr. Ron Gillespie of the Facilities Services Section, WTC, for setting up the pilot-scale clarifiers and associated equipment for the study.

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TREATMENT OF BIRD CHILLER WATER FOR REUSE IN FLUMING BROILER GIBLETS

by

H. S. Lillard *

INTRODUCTION

There are over 400 federally inspected broiler processing plants in the United States. A typical plant processes about 9000 birds per hour or about 70,000 per day. Modern processing methods make liberal use of water which, by federal inspection regulations, has to be of potable quality (1). Water shortages in certain areas and the rising cost of potable water and effluent discharge are cause for concern. Total water usage in the average plant is about 1 million gallons per day. One of the largest plants in Georgia, processes 200,000 birds per day, and reports using 30 million gallons of water per month at a cost of about $27,000 for potable water and effluent discharge.

Carawan *et al.*, in an EPA sponsored study, showed that the gizzard machine and giblet flumes required the most water and accounted for about 30% of the potable water used in the plant surveyed (2). Therefore, I studied the giblet operation in the first phase of a program which has two main objectives: (1) To examine the requirement for potable water in all phases of processing except scalding; (2) To determine the feasibility of conserving water in poultry processing plants by reusing water from a relatively clean process in another process. This report is a review of my work to date in the area of water reuse. Further details on methodology and results are available in the original references cited.

FEASIBILITY STUDY OF WATER REUSE

The initial step of studying the feasibility of reusing processing water was to compare the microbial populations of both water and product from various processing points in a commercial plant where potable water is used and, therefore, represents the best available technology. Table 1 shows that the level of fecal coliforms in water from the giblet flume was significantly higher than that in water from the giblet chiller but that the levels in the products from both sources were not significantly different. These results led to the conclusion that quality of processing water is not necessarily

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directly related to quality of product and, although processing water washes off loosely attached microorganisms, bacteria that are attached to the skin of broilers probably remain attached and cannot be washed off (3).

TABLE 1. MICROBIOLOGICAL QUALITY OF WATER AND PRODUCT FROM GIBLET FLUMES AND CHILLERS

Sample Source	WATER (52 samples) [1] Fecal coliforms (mean $\log_{10}$/ml)	Salmonellae No.+/total	PRODUCT (78 samples) [1] Fecal coliforms (mean $\log_{10}$/ml)	Salmonellae No.+/total
Giblet flume	3.00	15/52 a	2.32 b	4/78 c
Giblet chiller	2.10	18/52 a	2.30 b	4/78 c

[1] The same lower case letter follows values which are not significantly different at the 5% level.

Results of a microbiological evaluation of water from another processing plant are shown in Table 2.

TABLE 2. MICROBIOLOGICAL QUALITY OF PROCESSING WATER

Water Source	Mean $\log_{10}$/ml (Based on 26 samples) Aerobic counts [1]	Fecal coliforms [1]
Neck flume	3.81 a	3.11 b
Neck chiller	3.87 a	3.44 b
Bird chiller	3.49 a	2.48 b

[1] The same lower case letter follows values which are not significantly different at the 5% level.

These data show that aerobic counts and fecal coliform levels did not differ significantly in processing water from the neck flume, neck chiller and the bird chiller (4).

These two surveys showed that for water and energy conservation, water from the bird chiller might be used to flume and cool giblets without adversely affecting product quality.

FLUMING NECKS WITH UNTREATED BIRD CHILLER WATER

Necks were used in the next phase of this study because they represented the least cost to the processor. A 1/4 scale simulated giblet flume was constructed in cooperation with a commercial processor (Fig. 1). In an area away from the main processing plant, necks were flumed with potable water or with bird chiller water pumped from the overflow. Holding time of necks and ratio of necks to water in the simulated flume were the same as for the commercial flume in this plant. Necks flumed with bird chiller water were compared with those flumed with potable water in the simulated flume. Salmonellae incidence and levels, fecal coliform levels and shelf-life were the same for necks flumed with untreated bird chiller water and those flumed with potable water. However, aerobic counts were 1/4 log higher for necks flumed with bird chiller water than for necks flumed with potable water (5).

To eliminate this difference in counts treatment of the chiller water was necessary. Regulatory approval for reuse of chiller water without further improvement would be denied on the basis of esthetic considerations. Therefore, chlorination of bird chiller water without further improvement was not considered the best approach. Rogers (6), in an EPA sponsored study, screened various methods for removing organic matter from chiller water. The method he found the most promising was to filter the chiller water through diatomaceous earth in a pressure leaf filter. Therefore, I next undertook to evaluate the microbiological, chemical and physical properties of bird chiller water filtered through diatomaceous earth (DE) (7), and to evaluate the effect on necks of fluming with DE-filtered chiller water with and without chlorination (8).

TREATMENT OF CHILLER WATER

Figure 2 is a schematic diagram of a DE pressure leaf filter and the line of flow. A 1:1 w/w mixture of two grades of DE (Speedflow plus Dicalite 4200) was used to coat the 6 leaves prior to filtering the chiller water.

Filtration of bird chiller water through diatomaceous earth significantly lowered solids and grease contents (Table 3).

Filtration also improved the microbiological quality of chiller water. Reductions in aerobic counts and fecal coliforms were significant at the 1% level (Table 4).

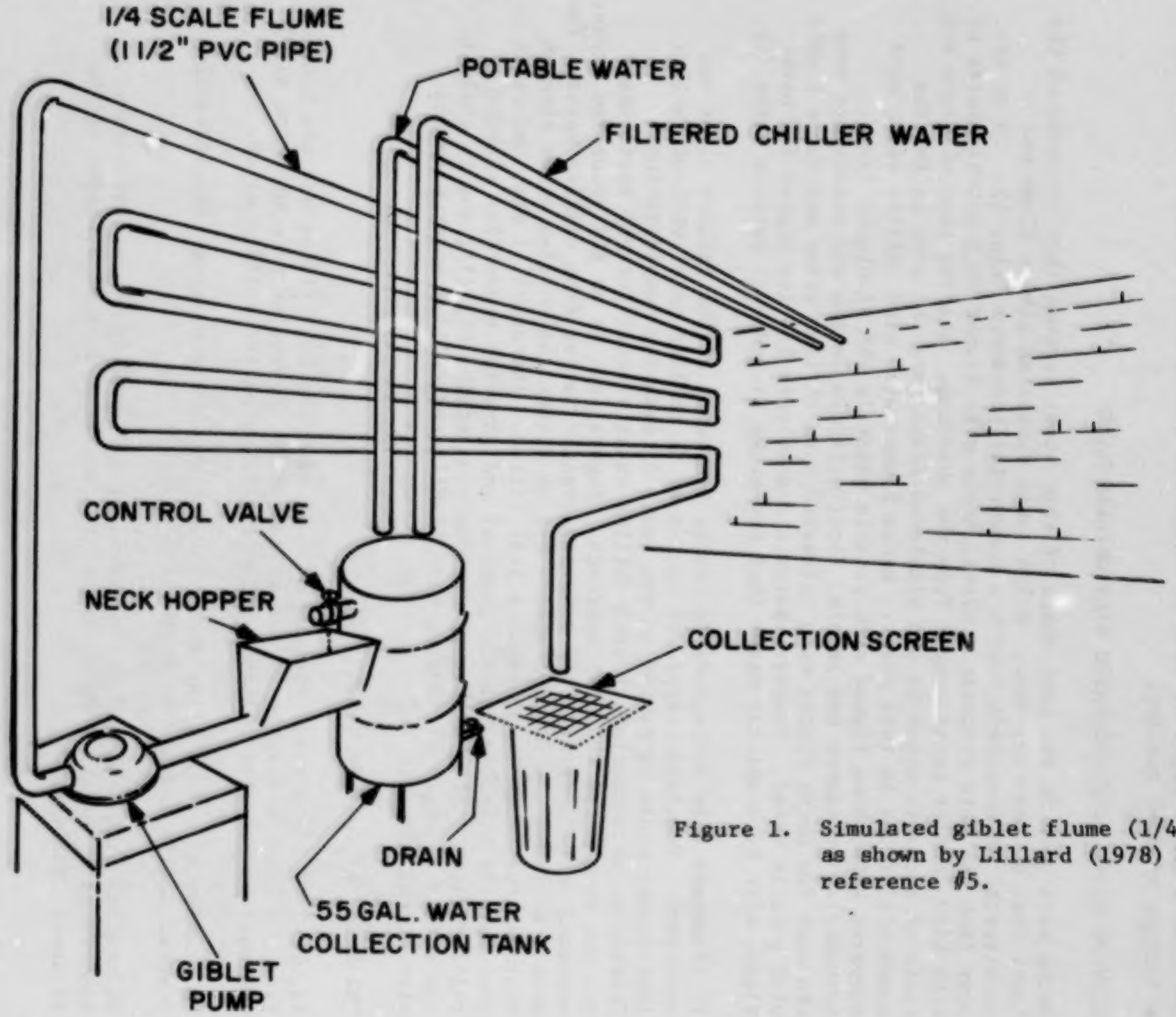

Figure 1. Simulated giblet flume (1/4 scale), as shown by Lillard (1978) in reference #5.

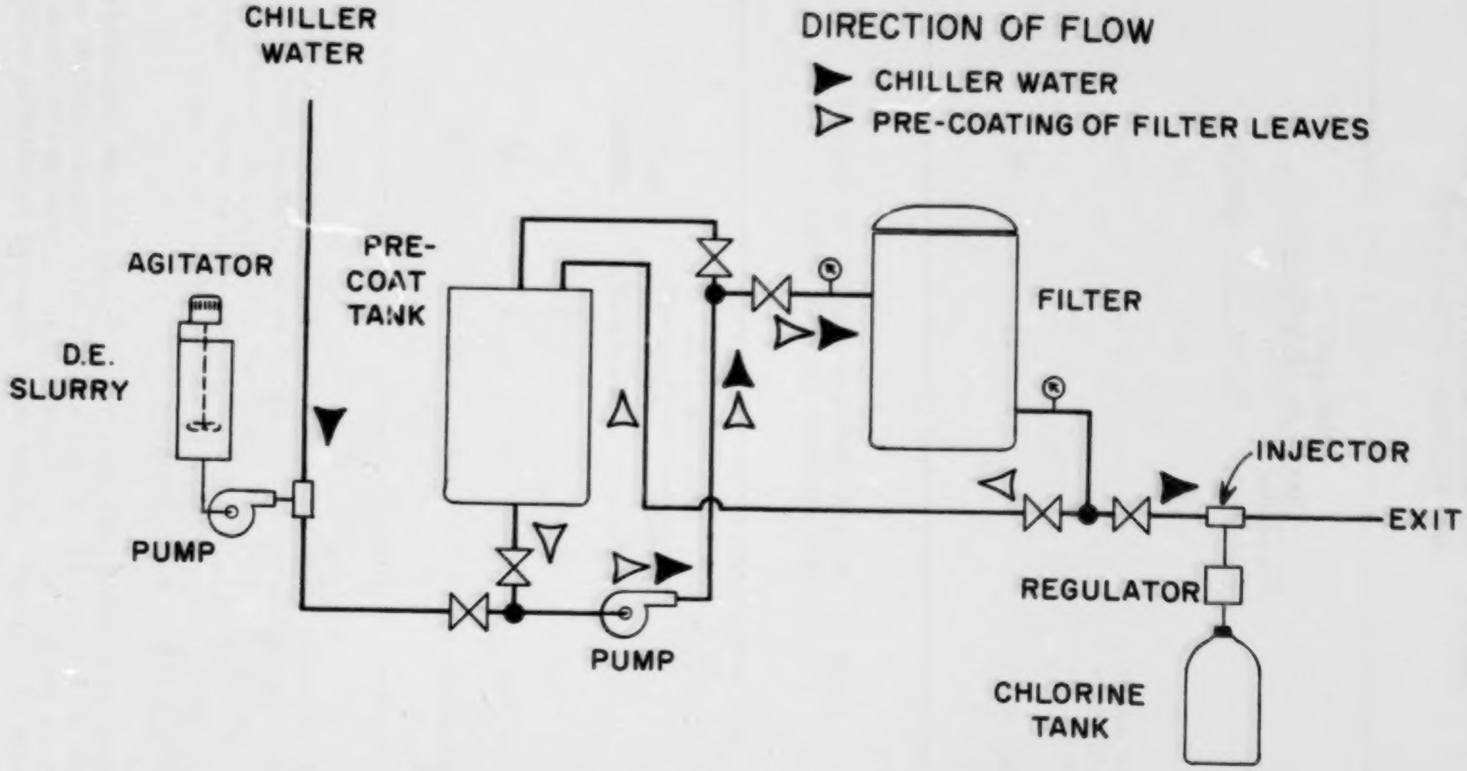

Figure 2. Schematic diagram of pre-coat tank, pressure leaf filter, and chlorinator. Arrows show the line of flow. As shown by Lillard (1978) in reference #7.

TABLE 3. CHEMICAL PROPERTIES OF CHILLER AND FILTERED CHILLER WATER

Water Source	Mean mg/l (Based on 18 samples) Suspended Solids	Dissolved Matter	Grease
Chiller water	160	414	137
Filtered chiller water (1:1 w/w Speedflow + Dicalite 4200)	9	324	16
Percent reduction due to filtration	94	22	88

TABLE 4. MICROBIOLOGICAL QUALITY OF CHILLER AND FILTERED CHILLER WATER

Source	Mean $\log_{10}$/ml Aerobic count	Fecal coliforms	No. of samples
Chiller water	5.12	3.13	18
Filtered chiller water	3.72	1.33	18
Filtered, chlorinated chiller water	1.45	<0	10

Microbiological quality of the water was further improved by chlorination. Removal of organic matter from chiller water by filtration made it possible to chlorinate effectively with low levels of chlorine gas (26-28 ppm) instead of the 48-50 ppm required for untreated chiller water. Table 4 shows that after chlorination, filtered chiller water was comparable in microbiological quality to potable water (7).

The filtered water was clear, and relatively colorless and transmitted 91-100% of light at 540 nm; it was not esthetically objectionable; and it visually resembled potable water. Figures 3 and 4 show the extremes in color and clarity of filtered chiller water compared to potable water.

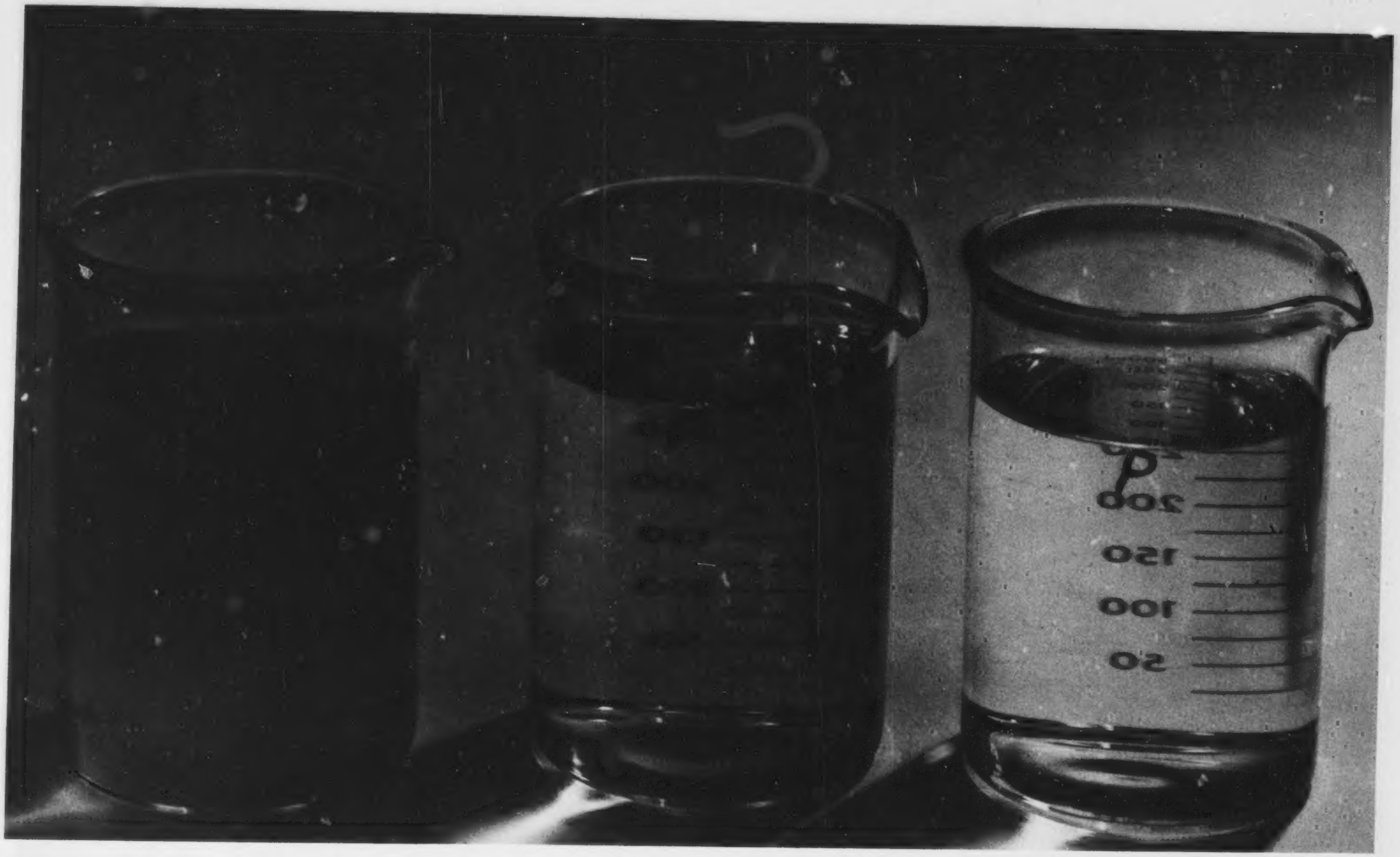

Figure 3. Water samples (left to right): from the bird chiller, filtered chiller water and potable water as shown by Lillard (1978) in reference #7.

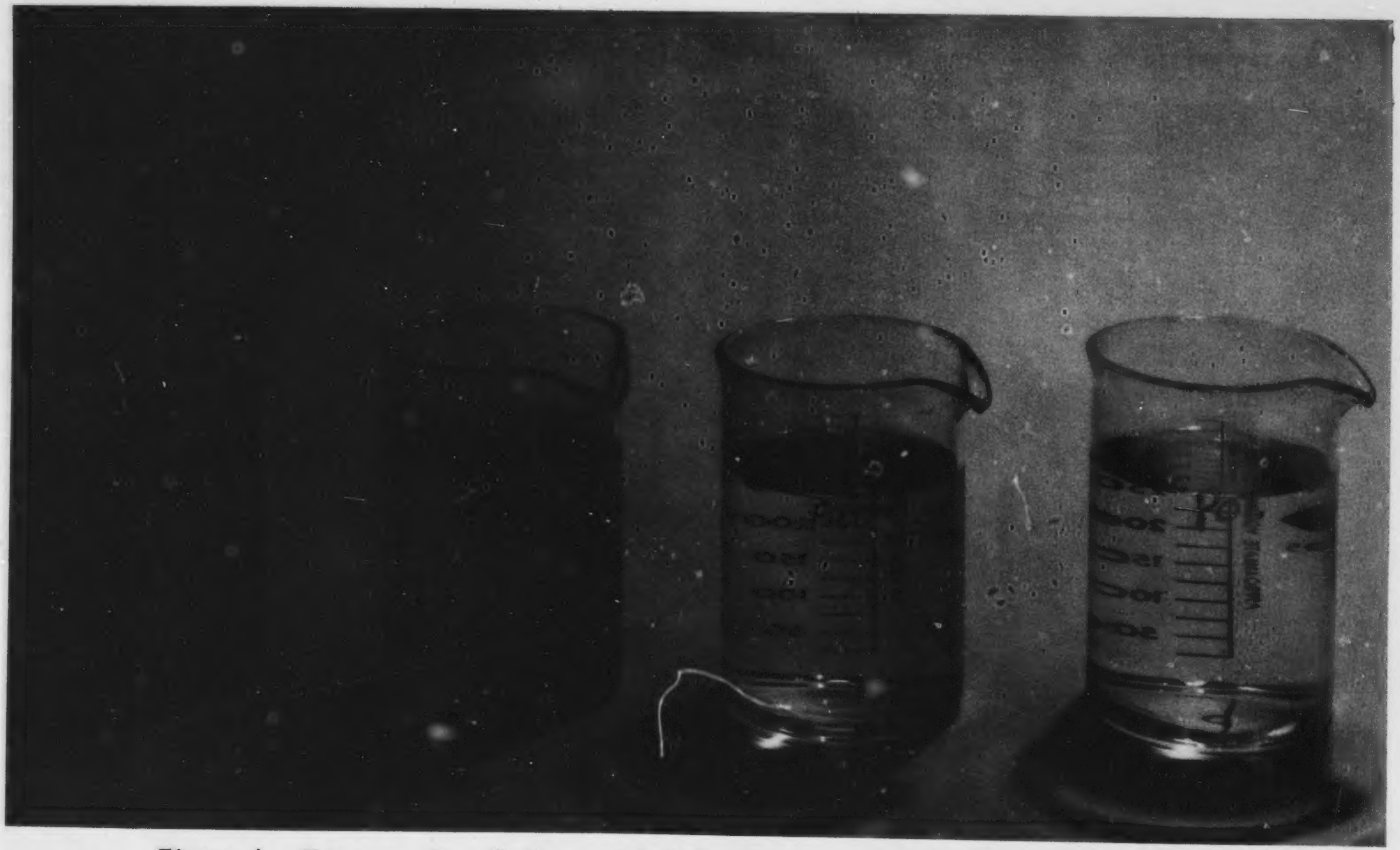

Figure 4. Water samples (left to right) from the commercial flume, bird chiller, filtered chiller water and potable water as shown by Lillard (1978) in reference #7.

Fig. 3 shows the maximum color obtained; Fig. 4 shows the clearest water obtained, with or without chlorination, which resulted in 100% light transmission at 540 nm.

In Fig. 4 clarity of the filtered chiller water, unfiltered chiller water or commercial flume water is best compared with that of potable water by the ease with which markings on the beakers can be seen through the water. When necks are flumed with potable water, the appearance of the water changes within seconds of the necks entering the flume. Fig. 4 shows the dark (bloody) characteristics of commercial flume water and the grease floating on the surface. By contrast, filtered chiller water is relatively clear, colorless and free of grease. Considering the chemical, physical and microbiological properties of the filtered chiller water discussed above and the rapid deterioration of potable water in the neck flume, the requirement for use of potable water in neck flumes does not seem necessary.

Necks flumed in the simulated line with potable water were then compared with necks flumed with filtered chiller water and with filtered, chlorinated chiller water. Temperature of necks flumed with chiller water varied seasonally. However, during the course of this study, necks flumed with chiller water were 12°C cooler than necks flumed with potable water. Table 5 shows that, microbiologically necks flumed with potable water and necks flumed with filtered chiller water or filtered, chlorinated chiller water were not significantly different.

TABLE 5. MICROBIOLOGICAL CHARACTERIZATION OF NECKS FLUMED WITH POTABLE WATER, FILTERED CHILLER WATER AND FILTERED, CHLORINATED CHILLER WATER

Source of flume water	Mean $\log_{10}$/ml		
	Aerobic counts [1]	Fecal coliforms [1]	Mean number days of shelf-life [1]
Potable water	5.48 a (12)	3.75 c (12)	14.2 e (30)
Filtered chiller water	5.45 a (12)	3.47 c (12)	14.2 e (30)
Potable water	5.17 b (10)	3.50 d (10)	11.7 f (25)
Filtered, chlorinated chiller water	5.27 b (10)	3.53 d (10)	13.0 f (25)

[1] The same lower case letter follows values which are not significantly different at the 5% level. The number of samples per mean is given parenthetically.

CONCLUSIONS

In accordance with federal regulations and technology, giblets are flumed with potable water. My work has shown that product quality can be equally good when water of somewhat less than potable quality is used: necks flumed with chiller water filtered through diatomaceous earth were microbiologically equal in all respects to necks flumed with potable water. Fluming giblets with filtered chiller water would reduce the demand of poultry processors for potable water and energy, and also would reduce the amount of water and organic matter discharged into municipal waste treatment systems.

According to estimates a processor could recover the cost of a pressure leaf filter in less than 2 years (7).

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DESIGN AND OPERATION OF A VEGETABLE OIL PLANT WASTEWATER TREATMENT SYSTEM FOR FUTURE STANDARDS

by

N. J. Smallwood*

INTRODUCTION

Lou Ana Foods, Inc., operates a medium-size vegetable oil refining and processing plant in Opelousas, Louisiana. The plant is operated continuously except for shutdown on major holidays.

Because of ownership and management changes in the early 1970's, attention was not directed to achieving compliance with the Federal Water Pollution Control Act until 1975. It was then concluded that the company did not have the technical resources to successfully handle the project. A search was initiated to obtain the necessary expertise. By June, 1976, the company was able to acquire the services of a competent consultant and recruit experienced technical management who were able to utilize the best methods and designs which had evolved from the vegetable oil industry. The result of the work has been to meet the NPDES schedule of compliance and effluent limits, and, we believe, to provide a system for meeting future standards. The purpose of this presentation is to share with the vegetable oil industry and the Environmental Protection Agency our concept, design, operating mode, results, and conclusions pertaining to vegetable oil wastewater treatment.

SYSTEM OBJECTIVES

The scope and design of the Lou Ana Foods' wastewater treatment project were to meet the following objectives:

1. Meet the NPDES schedule of compliance and effluent limits.
2. Achieve a level of reliability to not jeopardize continuity of plant operations or exceed effluent limits.
3. Provide water treatment capacity for future expansion of production facilities.
4. Minimize operating costs.
5. Improve the esthetic image of the plant.
6. Satisfy Spill Prevention, Control, and Counter Measure requirements.
7. Accommodate future effluent standards with minimum capital cost.

WASTEWATER EFFLUENT FROM VEGETABLE OIL PROCESSING

Sources and Characterization

The treatment system was designed to handle three categories of water effluent from manufacturing operations:

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1. Process Wastewater: Water which has been in contact with the product stream and contains some concentration of oil, processing reagents, and sludge material derived from crude vegetable oil.
2. Rainwater Runoff: Rainwater which falls on outside surface areas and initially washes away drips and spills from tank car and truck loading/unloading stations and tank fields.
3. Non-Contact Cooling Water: Wellwater remaining free of contamination while circulated once through a closed piping/coil system to maintain process temperature control.

Water Stream Separation and Collection

The system includes the following separation and collection by category:

1. Process Wastewater: The wastewater from each major source is individually piped for gravity discharge into a collection sump adjacent to the main processing building. Routine, visual observation, sampling and analysis can be made of each wastewater stream to detect anomolous conditions. From the collection sump, the wastewater flows by gravity through an underground line to the pre-treatment sump which is equipped with a mechanical agitator.
2. Rainwater Runoff: Outside areas subject to oil leaks, drips and spills are provided with concrete mats and dikes for containment. Underground drainlines are installed for gravity flow of rainwater/oil to a collection sump adjacent to the pre-treatment sump for process wastewater. The two adjacent sumps have a connecting line for gravity flow from the rainwater sump to the process wastewater sump. The connecting line contains a remote operated shutoff valve actuated by a raingauge device. Thus, in the event of a rain, the initial rainwater collected by the concrete mats and dikes wash and carry away any oil spillage to the rainwater collection sump and on to the process wastewater pre-treatment sump. If the rainfall continues for a prolonged period, after a preset level is reached in the raingauge, a signal is transmitted to a controller which will close the valve in the connecting line between sumps. The water level in the rainwater sump will rise until it reaches a high level overflow which will conduct, by this time, essentially pure rainwater to the non-contact cooling water outfall.
   Note: If rainwater runoff were allowed to indefinitely flow into process wastewater pre-treatment sump, then the subsequent treatment system would be overwhelmed by the quantity of water. The other alternative of sizing the subsequent treatment system to handle the complete rainfall load is not economically feasible.
3. Non-Contact Cooling Water: Non-contact cooling water lines are piped to discharge into a flash tank. Any steam generated will flash and vent to the atmosphere. From the flash tank, water is pumped to two oil-water separating decanters connected in series for removal of any entrained oil which could result in event of coil failure. Clean water underflows from the second decanter for gravity discharge through a weir box and a final gravity separator and on to the non-contact cooling water outfall.

TREATMENT TRAIN

The sequence of processes in the treatment train is pH adjustment, gravity separation of floatable oils, flow equalization, neutralization, dissolved air flotation, biological treatment and clarification.

pH Adjustment

A pH in the two to three range is required to achieve optimum gravity separation of floatable oils. Adjustment of pH is achieved by a control loop which monitors the wastewater in the pre-treatment sump and controls sulfuric acid addition to the sump for lowering pH as required.

Gravity Separation of Floatable Oils

Wastewater is pumped from the pre-treatment sump to four decanters for separation of floatable oils. The wastewater stream enters the first two decanters connected in parallel through a horizontal distributing nozzle located in the center of each vessel. Oil-water separation occurs in the horizontal center zone of each vessel with the floatable oil subsequently rising to the top of the liquid column. The accumulation of oil is pumped off each day by means of a swinging suction. The water fraction is continually drawn off by gravity underflow to the second two decanters connected in series for repetition of the process. Some of the solids in the wastewater stream settle to the bottom of the decanters. The decanter system is sufficiently sized to operate successfully with one parallel branch valved out of service for sediment removal.

Flow Equalization

Flow equalization for optimum operation of dissolved air flotation is achieved by means of eight 12,000 gallon capacity hold tanks. The hold tanks provide capacity for a minimum of 16 hours accumulation of wastewater at the present flow rate of 85 gpm. Other than for flow equalization, the hold tanks function as settling tanks for further removal of settleable solids and gravity separators for further recovery of floatable oil. The hold tanks can be individually valved out of service for removal of accumulated floatable oil and sediment without disrupting normal operation of the system.

Neutralization

Wastewater is pumped from the hold tanks to the dissolved air flotation process. On the suction side of the transfer pump, caustic soda is injected to neutralize the water stream. Primary neutralization control is provided by an automatic control loop. Manual control is provided for backup operation.

Dissolved Air Flotation

Neutralized water and a cationic polymer coagulant are discharged into a two compartment flocculation tank with high and low speed mixing agitators respectively. From the flocculation tank, the water overflows to the inlet of a center-positioned coagulation tube in the flotation cell. Water underflows from the flotation cell through six exterior riser tubes to a top peripheral collection ring for both recycle pressurization and gravity discharge to an aerated lagoon. Water recycled at about 350 gpm is fully pressurized and is injected with an anionic polymer coagulant aid prior to discharge back into the coagulation tube. Removal of float is accomplished by a top rotating skimmer. The DAF is sized to provide a surface loading of less than 3.0 gpm/sq ft.

Biological Treatment

Biological treatment is accomplished by means of an aerated lagoon. The lagoon capacity is 11.2 million gallons with a normal water depth of 16 feet. A redwood baffle separates the lagoon into two sections. Aeration is achieved by eight 40-horsepower floating aerators. Liquid fertilizer is injected into the lagoon influent to supply nitrogen and phosphorus for the microorganism life processes. The perimeter wall of the lagoon is concrete lined to preclude erosion. At the present wastewater influent rate, the lagoon provides 90 days of retention time.

Clarification

Treated water is pumped from the aerated lagoon to a clarifier for separation of the biological sludge. The clarifier is sized for an overflow rate of 450 gpd/sq ft of surface area and a retention time of three hours. Clarified water gravity flows to a final monitoring station. The biological sludge is recycled back to the inlet side of the aerated lagoon.

Final Monitoring

Prior to discharge to the outfall, the treated water flows through a monitoring station for flow measurement, sampling, and pH recording.

OPERATION

Time

With more than 16 hours hold capacity, the dissolved air flotation process (DAF) is operated only eight hours per day. Furthermore, the clarifier is operated and treated water is discharged only during the period that the DAF is in operation. Operating the critical elements of the system only during the day shift provides the opportunity for maximum attention and control.

Reliability

The treatment system in contact with acidic wastewater is constructed primarily of fiberglass reinforced plastic (FRP). Consequently, it is essentially maintenance free. Both pH control loops for sulfuric acid and caustic soda addition respectively have backup manual control. Critical pumps in the system are paired and are installed in parallel. Operation of the total system would be seriously impaired only in the event of mechanical breakdown of either the DAF or clarifier. However, up to 16 hours per day repair time is available for both the DAF or clarifier. With excess retention time available in the aerated lagoon, the DAF could probably be bypassed for up to five days without significant consequences. Sufficient freeboard is available in the aerated lagoon to hold water for at least five consecutive days to accommodate major repair of the clarifier.

RESULTS

Completion

Construction of the wastewater treatment system was completed and startup achieved to meet the July 1, 1977, NPDES schedule of compliance.

Performance

Performance results from operating the treatment system eight months are given in Table 1.

Project Cost

The total cost of the treatment system project was $1.5 million.

Operating Expense

Annual operating expense for the total system based on actual experience to date is given in Table 2.

Reliability

The system has been operated continually since startup without any significant problems. However, the necessity of manual pH control backup and other reliability features described has already been demonstrated.

CONCLUSIONS

With disciplined operation and maintenance of the treatment system, it appears that meeting BOD, O&G and pH limits will not be a problem.

It is too early in the life of the system to predict the expected long-term performance on suspended solids removal. After the microorganism population in the aerated lagoon has reached optimum level, it will be possible to better access clarifier performance and suspended solids removal.

System performance can be further improved by optimizing treatment conditions for each type of vegetable oil refined. Wastewater from cottonseed, corn, soybean and sunflowerseed oil refining/acidulation is relatively easy to treat. Coconut and peanut oil wastewater being more emulsified is more difficult to treat.

Use of decanters and hold tanks for floatable oil and settleable solids removal is assessed to be better than conventional fat traps or API type separators in overall operation.

TABLE 1. WASTEWATER TREATMENT SYSTEM PERFORMANCE

Effluent Characteristics for Treatment Train Processes

Process	Concentration (mg/l)				
	COD	BOD	O&G	TSS	pH
1. Collection-pH Adjustment Sump	38,333	10,850	8,107	12,461	2.1
2. Decanter	-	-	2,635	9,014	2.1
3. Equalization - Hold	15,000	7,692	577	905	2.2
4. DAF	4,053	5,972	282	589	6.5
5. Aerated Lagoon	547	123	4	608	7.0
6. Clarifier	161	16	4	66	7.2

Performance for Each Treatment Train Process

Process	Percent Removal			
	COD	BOD	O&G	TSS
1. Decanter	0	0	67.5	27.7
2. Equalization - Hold	60.9	29.1	78.1	90.0
3. DAF	73.0	22.4	51.1	34.9
4. Aerated Lagoon	86.5	97.9	98.6	-
5. Clarifier	70.6	87.0	0	89.1
6. Total Treatment System	99.6	99.8	99.9	99.5

Treatment Performance with Respect to NPDES Limits

	Minimum	Average	Maximum
Flow Rate (MGD)	0.066	0.121	0.178
BOD (lb./day)	4	17 (104)	47 (256)
O&G (lb./day)	1	4 (41)	10 (104)
TSS (lb./day)	17	68 (104)	156 (256)
pH	7.0 (6.0)	7.2	7.4 (9.0)

Note: NPDES limit conditions given in parenthesis

TABLE 2. ANNUAL OPERATING EXPENSE FOR THE TOTAL WASTEWATER TREATMENT SYSTEM

Expense Item	Cost
1. Labor	$29,370
2. Operating Supplies	
a. Sulfuric acid	20,672
b. Caustic soda	34,712
c. Flocculant agents	24,000
3. Maintenance (Material & Labor)	27,000
4. Utilities	
a. Steam	4,876
b. Electrical Power	49,304
5. Sludge Disposal	17,600
6. Miscellaneous	5,000
7. Depreciation	79,320
TOTAL	$291,854

Wastewater Treatment Cost = $6.89/1,000 gallons

Disposal of sludge from the treatment system is a challenging problem. We are still seeking a satisfactory, long-term solution.

Overall, based on results achieved to date, it can be concluded that the wastewater treatment system has and will continue to meet design objectives.

DISSOLVED AIR FLOTATION TREATMENT
OF
GULF SHRIMP CANNERY WASTEWATER

by

A. J. Szabo, Larry F. LaFleur, and Felon R. Wilson*

INTRODUCTION

The plant scale dissolved air flotation project for treatment of a Gulf Coast shrimp cannery wastewater and other cannery pollution abatement measures are discussed. The system was installed as a joint industry-government demonstration project to establish achievable levels of pollutant removals from wastewaters during shrimp processing and during oyster processing. This project was the follow-up of an earlier pilot study sponsored by the American Shrimp Canners Association and the Environmental Protection Agency (1).

As reported by Ertz,et al, to the Eighth National Symposium on Food Processing wastes (2), the dissolved air flotation process has been tested on a pilot scale for several seafoods and has been installed full scale to treat tuna and other fish wastewaters. This treatment process has advantages of minimal land requirements and quick start up, and is particularly adaptable to the seasonal, intermittent operations of the land-poor Gulf shrimp processors. Chemical coagulation and pH adjustment to precipitate colloidal and suspended solids in proteinaceous seafood wastewaters for removal by flotation is considered to be a practicable and presently available technology which could be substituted for the less adaptable biological process. Plant scale system performance should, therefore, be of interest to industry and to regulatory and other governmental agencies.

BACKGROUND

Gulf shrimp canners have for many years been concerned with their wastewater disposal problem. These processors have sought solutions individually and collectively. Several manufacturers and suppliers have installed and operated test units, ranging from screening and flotation to reverse osmosis. This project sought to develop practicable wastewater management and treatment data from a plant scale installation under normal cannery operating conditions. The association (ASCA) obtained a demonstration grant and funded the studies, design, installation and operation of the facilities at the Violet Packing Company cannery south of New Orleans. Information obtained will be of assistance to all shrimp processors in their pollution abatement programs.

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CANNERY WASTEWATER

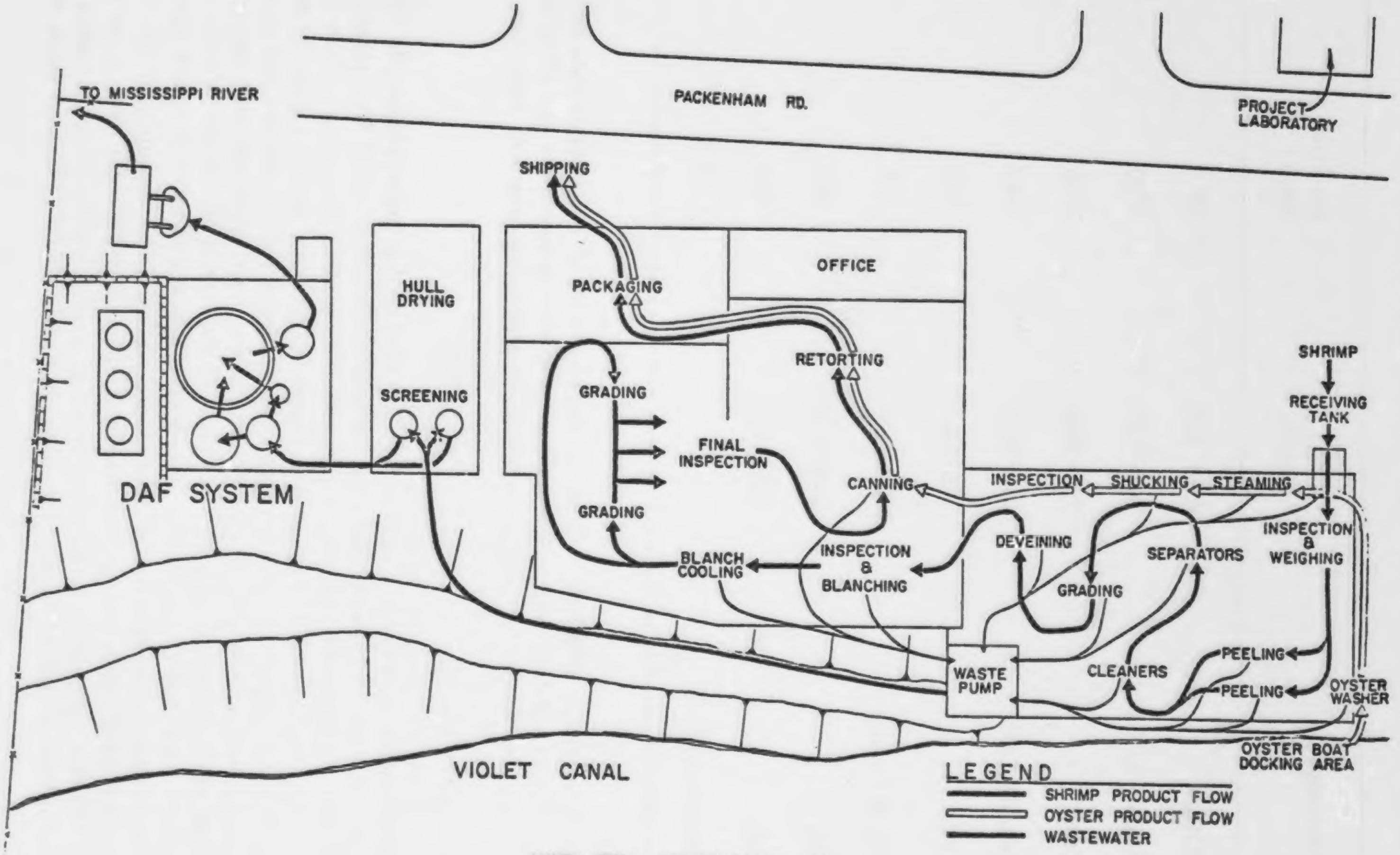
The Violet Packing Company shrimp and oyster processing and canning layout schematic is shown in Figure 1. Wastewaters flows from unit processes were characterized at the start of the study. Sources, volumes and concentrations as developed in 1975 are shown in Table 1.

TABLE 1. UNIT PROCESS WASTEWATERS, GULF SHRIMP CANNERY

Process	Flow			Concentration-mg/l		
	Gallons/ 1000 lbs.	M^3/KKG	% of Total	BOD5	O & G	TSS
Receiving	143	1.193	1.9	4,278	650	1,711
Peelers	2,825	23.550	38.0	2,375	257	963
Separators	572	4.770	7.7	899	34	401
Graders	237	1.976	3.2	395	12	190
Deveiners	1,289	10.750	17.3	366	14	211
Canning Room	2,373	19.760	31.9	781	17	329

After study, a water conservation and wastewater management plan was adopted and the cannery made considerable improvement which affected water use. Total wastewater volumes were reduced by 43% from 7,728 gallons per 1000 pounds (64.4m^3/KKg) of raw shrimp processed to 4,420 gallons per 1000 pounds (36.9 m^3/KKg) between 1974 and 1977. Cannery pollution abatement procedures resulted in the significant reduction of total pollutants in the wastewater during this period.

The treatment facilities were designed to treat screened wastewater from the cannery at a flow rate of 700 gallons per minute (2.6 m^3/minute). By the time the system was put into operation, the flow had been reduced to 500 gpm (1.9 m^3/minute). The concentrations of the Violet Packing Company 1977 wastewater flows after pretreatment through 10 mesh (0.85 mm) vibrating screens are given in Table 2.



VIOLET PACKING CO.
VIOLET, LOUISIANA

Figure 1

TABLE 2. GULF SHRIMP CANNERY WASTEWATER CONCENTRATIONS

Parameter	Range (mg/l)	Average (mg/l)
BOD5	450-1620	1070
Soluble BOD5	265-1120	720
COD	1388-3920	2775
Soluble COD	1032-2960	1880
TKN	156-344	260
Oil & Grease	28-169	115
TSS	240-1020	505
VSS	188-892	425
pH (Units)		7.5

As evident from the range of values in Table 2, the character of wastewaters from shrimp canning operations is not consistent. The lack of uniformity is due to the variation in size, age and type of raw product and to variations in processing rates and water use.

TREATMENT FACILITIES

A multi-modal dissolved air flotation system was installed at the Violet cannery in 1976. It consisted of complete facilities to treat the cannery wastewaters in full flow pressurization, partial flow pressurization or recycle pressurization modes. An influent flume flow meter recorder-controller served to proportion chemical dosages. Acid (or caustic) dosages into the influent surge tank were pH meter-recorder-controller actuated and equalization flow was returned to this tank. Treatment process pumps pressured the injected air and wastewater mixture into the retention tank at full flow mode or pumped into the flocculation tank in partial or recycle modes. Coagulant was added to the influent flume and coagulant aid was injected into the flotation cell influent line downstream from the manual pressure control valve and/or into the flocculation chamber. Wastewater entered the circular flotation cell center coagulation chamber in which pressure was released and the suspended solids-air bubble mixture moved upward and radially. Floated solids accumulated on the surface as skimmings and were swept by four rotating scraper arms over a beach and chute into the skimmings hopper. Clarified wastewater flowed radially and downward to effluent tubes, up and over the circumferential weir and into the effluent tank. Prior to discharge, pH was adjusted with caustic feed controlled by the effluent pH meter-recorder.

In the partial flow pressurization mode, part of the flow (50%) was routed as above for the full flow mode and the remainder of the wastewater flow was pumped to the vertical, cylindrical flocculation tank with mixer, after pH adjustment and coagulant feed, for a 20 to 30 minute slow mix. It then flowed by gravity to the center, coagulation chamber of the flotation cell where it was mixed with the pressurized flow containing coagulant and coagulant aid.

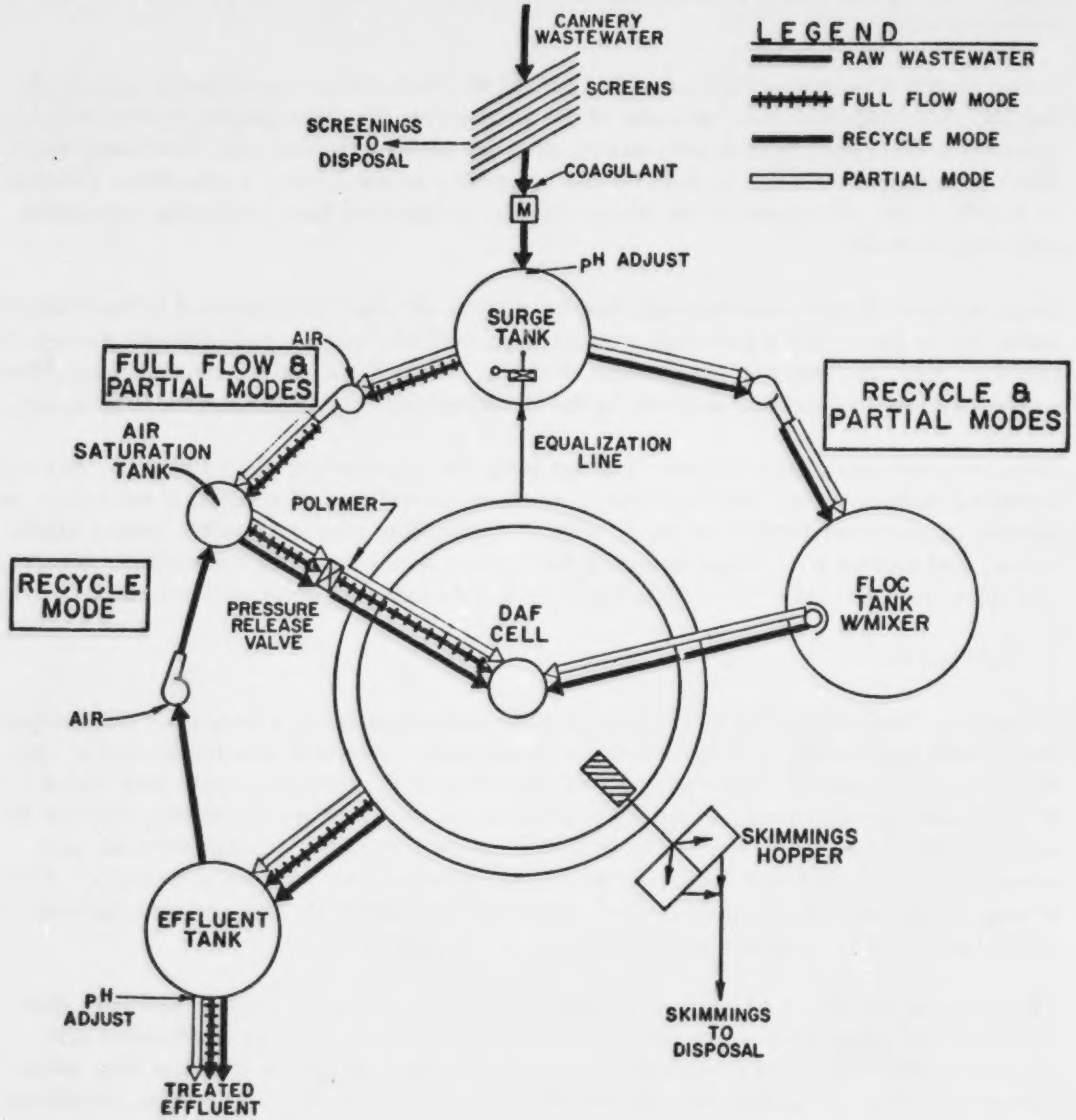
Recycle pressurization was accomplished by routing all chemically treated influent wastewater to the flocculation tank and pressurizing clarified flotation cell effluent through the retention tank and into the coagulation chamber, where the dissolved air and flocculated wastewater were mixed and released in the flotation cell. Figure 2 shows the DAF layout.

The DAF treatment system included storage tanks for liquid alum, liquid caustic, and concentrated sulfuric acid. The flow meter recorder-controller, pH controller-recorders, proportioning chemical feeders for acid, alum and coagulant aids (two units), power supply meter, and central panel were designed for system control and data collection. An on-site laboratory was installed and equipped to enable analyses to be timely made.

OPERATIONS

In order to confirm pilot plant findings on chemical coagulant and coagulant aid dosages, bench tests were made on Violet Cannery wastewater. Maximum precipitation and clarification was repeatedly shown to occur at pH 4.5 to 5.0, although ranges from about 2.0 to 11.0 were investigated. Coagulants tested were: alum, chitin (chitosan), glucose trisulfate (GTS), iron salts, lignosulfonate, and cationic polymer. Coagulant aids used were: Magnifloc 835A and Magnifloc 845A, as recommended from the pilot study. Promising results were obtained with alum, lignosulfonate (PRA-1), and cationic polymer (507C) as coagulants combined with polymers 835A and 845A.

Operation of the new DAF wastewater treatment system met with start up problems that "just couldn't happen here". Completion of equipment delivery and installation was about two weeks after start of the heavy canning season. Problems with the flow meter-controller, chemical pumps, pH meter-controller, process pumps, flocculator, flotation cell, and electrical system were slowly resolved while the supply of product was being used up and was dwindling. By the time some of the equipment and installation difficulties were resolved, the primary, summer season had passed. Other discrepancies in the flotation cell coagulation tube and the inadequacy of skimming arms were rectified and some operations were possible during the limited fall 1976 canning season. Other necessary modifications were completed prior to the 1977 summer season so that full operations



DAF TREATMENT PLANT SCHEMATIC

Figure 2

and data collection were possible.

The dissolved air flotation treatment plant was first operated as a physical treatment system, without any chemical addition. Limited removals of BOD5 and oil and grease were accomplished, and solids existing in suspension were effectively reduced. Removals attained were: BOD5 - 3.5%; Oil and Grease - 10.5% and TSS - 69.4%.

Physical-chemical treatment was the primary objective and most efforts were directed toward obtaining optimum performance. In all circumstances, pH was controlled between 4.5 and 5.0 by the addition of sulfuric acid. Coagulants were added to the system influent stream and coagulant aid was injected into the pressured flow entering the flotation cell and/or into the flocculation tank. Effective pH control and coagulant-coagulant aid additions resulted in significant removals of the conventional pollutants. Full flow pressurization mode average removal performance levels are shown in Table 3 by types of coagulant applied.

TABLE 3. DAF TREATMENT OF GULF SHRIMP WASTEWATER, COAGULANT COMPARISON

Coagulant -Dosage (mg/l)	Coagulant Aid -Dosage (mg/l)	Per Cent Removal			No. Test Runs
		BOD5	TSS	O & G	
PRA-1 60	835A 2.5	56.7	73.3	67.7	3
507C 300	835A 5.0	68.5	56.8	71.1	2
Alum 219	835A 3.9	48.5	62.7	87.3	23

Pressurization modes were compared using alum and polymer. Influent flow pH was adjusted to 5.0, alum was added to the influent, and polymer was added to the pressure control valve discharge. These data (Table 4) were collected under carefully controlled operating conditions and reflect maximum attainable results.

TABLE 4. DAF TREATMENT OF GULF SHRIMP WASTEWATER, MODAL COMPARISON

Mode	Average Alum (mg/l)	Average 835A (mg/l)	PerCent Removal BOD5	TSS	O & G
Full Flow	219	3.9	48.5	62.7	87.3
Partial	345	6.1	55.0	72.6	83.4
Recycle	283	7.5	64.6	64.8	83.6
Overall Average	271	5.8	56.5	65.6	85.0

It was realized that average industry treatment system operation could vary significantly from the atypical project conditions. In order to simulate anticipated conditions, several unattended, automated test runs in the full pressurization mode were sampled. Removals achieved with average dosages of 303 mg/l of alum and 3.7 mg/l of polymer were: BOD5 - 54.5%; TSS - 34.3% and O & G - 84%.

Because of the warm weather and the existing adjacent housing developments which prevail at most Gulf shrimp cannery locations, it is necessary to take positive action to control odors and insects around the wastewater treatment system, and the total cannery. The wastewater and the solids which are developed are highly putrescible and very odorous. Frequent washdown and use of insecticides is necessary. Treatment system tanks must be drained and washed when intermittent operations result in no fresh wastewater flows for 8 to 12 hours or longer. The additional pollutants discharged under such conditions can be calculated and cause further reduction in the effectiveness of the treatment system operation.

Inherent characteristics of shrimp processing operations contribute to some of the conditions which limit consistent and higher levels of achievable pollutant removals. Raw product types and sizes and age variations, processing rate changes and adjustments, stop and go and intermittent operations and possibly other factors are involved. The variable wastewater flow was found to be extremely sensitive to coagulant dosages and frequent adjustments were needed. The study plant air injection capabilities were limited. Air to solids ratios may, therefore, not have been fully investigated in the operation of the demonstration plant. An additional air source would have been helpful.

Solids developed by flotation separation and skimming from the surface of the dissolved air system main cell consist of about 6% solids, air and liquid. These solid wastes are highly odorous and objectionable and are difficult to store and handle. Bench scale tests were made to concentrate the solids by centrifuging, by heating, and by gravity. Chemical conditioning with a bench scale Purifax unit demonstrated a degree of stabilization. A pilot scale evaporator-dryer unit by Convap was operated. It appeared that skimmings concentration to about 25% solids may be feasible, with a corresponding three fourths reduction in volume. More investigation of waste solids handling, concentration and disposal is urgently needed to solve this real problem of DAF system operation on seafood wastewaters.

COSTS

Computations have been made of costs of DAF system installation and operation to treat Gulf shrimp processing wastewaters. These costs range from \$0.38 to \$1.03 per case of 24 - 4 1/2 oz. (128g) cans of shrimp, depending upon the annual production. Costs for a typical 8-peeler cannery are from \$120,000 to \$132,000 per year, varying with the number of days of operation, the amount of product processed and the volume of generated wastewater which must be treated.

OYSTER WASTEWATER

The shrimp wastewater DAF treatment system was utilized to treat wastewaters from oyster processing and canning for a four week period in early 1977. Flow rates were about one fourth as great as while processing shrimp. Screened oyster wastewaters contained higher suspended solids and lower concentrations of oil and grease and biochemical oxygen demand. Mean values were: BOD5 - 510 mg/l; O & G - 37 mg/l; TSS - 2,280 mg/l and settleable solids - 30 ml/l.

Operating without pH adjustment but with alum and polymer as coagulants, the DAF system designed for shrimp cannery wastewater treatment was effective in reducing the discharged pollutants. Mean percentage removals attained were: BOD5 - 43%; O & G - 56%; TSS - 89%; Settleable Solids - 99%.

SUMMARY

It may be concluded from this study that dissolved air flotation physical-chemical treatment of shrimp processing and oyster processing wastewaters can be effective in reducing conventional pollutants. Such a pollution abatement-treatment system for shrimp processors should include a program of water use and wastewater management, pre-screening, a recycle mode dissolved air flotation system with automated pH control, proportional coagulant and coagulant aid feeders, and a suitable solids handling system. An effective, satisfactory method of collecting, concentrating, storing, handling and disposing of screenings and skimmings solids is yet to be developed and now appears to be a major detriment to the effective operation of the DAF treatment system on shrimp processing wastewaters.

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UPGRADING A BREWERY
WASTEWATER PRETREATMENT FACILITY FOR
THE CITY OF WINSTON-SALEM

by

C.D. Malone*, R.M. Stein*, and T.D. Cornett**

INTRODUCTION

The malt beverage brewing industry produces in excess of 60 bil gal of wastewater annually. A large percentage of this wastewater discharges into municipal wastewater treatment facilities. Typical raw waste loads for the malt beverage brewing industries are presented in Table 1. The quantity of oxygen demanding materials and suspended solids generated requires a high level of treatment. This treatment is normally provided either at the brewery or at a municipal wastewater treatment plant. This paper reviews the treatment system and operation program developed by the City of Winston-Salem, North Carolina, for treatment of a brewery wastewater at the Archie Elledge Waste Treatment facility. The City of Winston-Salem operates a 36 mgd activated sludge waste treatment plant. The treatment plant provides both primary and secondary treatment. Primary treatment consists of bar screens, grit removal, and primary clarification; while secondary treatment consists of four 200-ft diameter trickling filters followed by activated sludge and chlorination. Excess biological and raw primary sludges are anaerobically digested and subsequently dewatered on sand drying beds. The dried sludge is applied directly to farm lands. Gas produced by anaerobic digestion of the sludges is utilized to generate all electrical power requirements. Figure 1 presents a schematic illustration of the Archie Elledge Waste Treatment Plant.

Operational problems were experienced at the Archie Elledge plant, because of an organic overloading of the secondary treatment system. The City and and its consultant, AWARE, Inc., evaluated alternatives to reduce the organic load to the secondary treatment facilities. The results of this evaluation indicated that pretreatment of the brewery waste was the most practical approach to the problem. Pretreatment of the brewery waste was selected for two major reasons.

1. The City of Winston-Salem has a number of industries which discharge concentrated wastes into the treatment system. Most industrial wastes are combined with domestic waste and diluted before reaching the treatment plant. The brewery waste discharges into a separate outfall with only 100 private residences and thus arrives at the treatment plant without significant dilution. Thus, the brewery waste was segregated and arrived at the plant as a concentrated stream.

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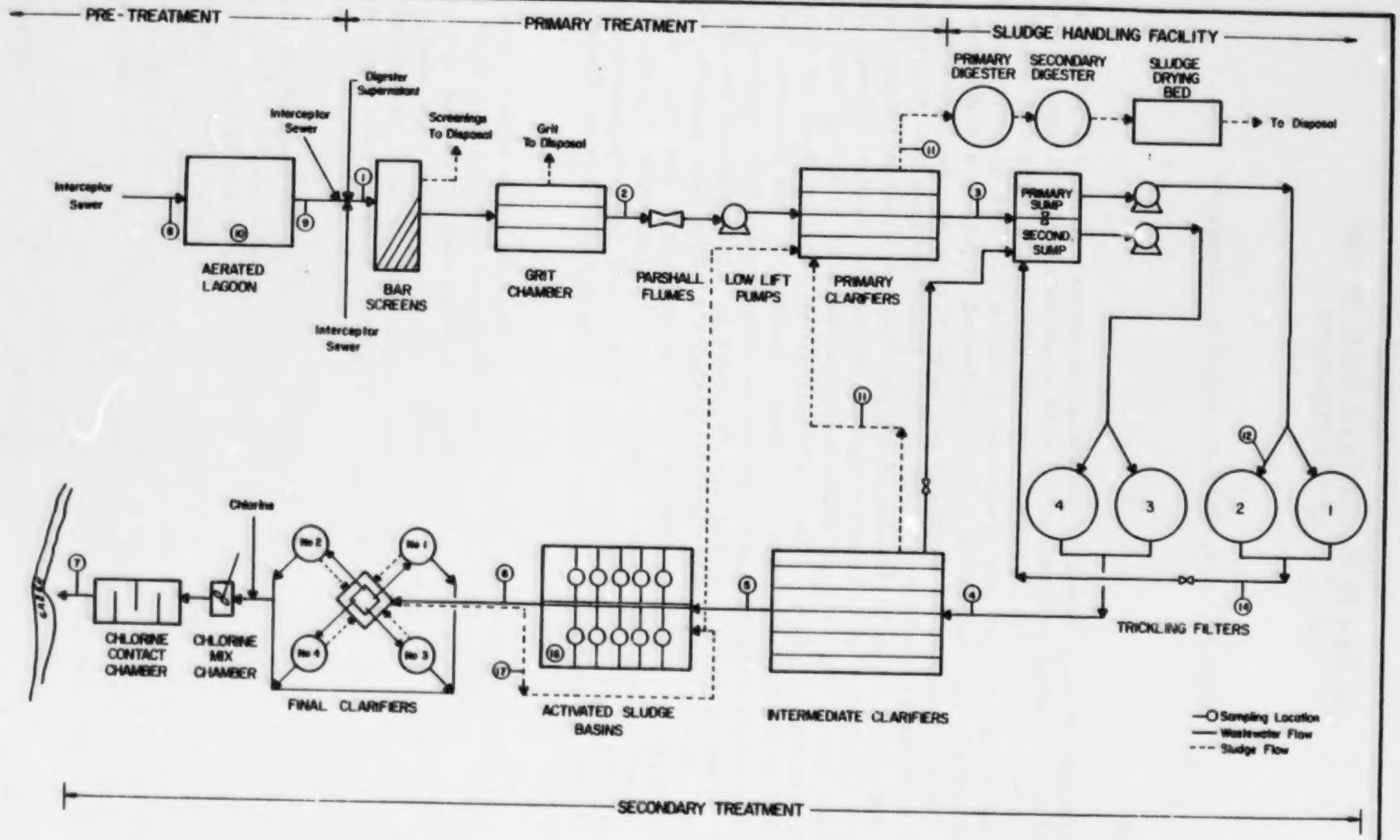


FIG. I . SCHEMATIC ILLUSTRATION OF THE MUNICIPAL WASTE TREATMENT PLANT

TABLE 1. TYPICAL RAW WASTE CHARACTERISTICS FROM MALT BEVERAGE PRODUCTION

	Average Range	Brewing Industry Mean Raw Waste Loads per Bbl of Beer[c]
Raw Waste Volume	2649.5-30280 m^3	971.46ℓ/bbl beer[b]
Raw Waste BOD	1400-2000 mg/1[a]	1.37 kg/bbl beer[b] (1622 mg/1)
Raw Waste Suspended Solids	500-700 mg/1[a]	.56 kg/bbl beer[b] (772 mg/1)

[a] Federal Guidelines, State and Local Pretreatment Guidelines, Construction Grants Program Information, EPA-430/9-76-017c, January 1977.

[b] EPA Technology Transfer Series, Capsule Report 6, Pollution Abatement in a Brewing Facility. Prepared by U.S. EPA.

[c] One barrel contains 117.18 liters.

2. The potential for developing filamentous organisms could be reduced by pretreatment of a predominatly carbohydrate brewery waste prior to the activated sludge system.

Table 2 presents a summary of the brewery raw wastewater characteristics as it enters the Elledge plant. This discharge includes the brewery, the brewery container manufacturing plant wastes, and a small domestic contribution. The brewery wastestream comprises approximately 35 percent of the total BOD loading to the waste treatment plant and approximately 10 percent of the total plant flow.

The pretreatment system was developed in two phases. The initial phase of the brewery pretreatment facilities, constructed in 1971, consisted of a 1.33 mil gal aerated lagoon with an installed horsepower level of 360. The system was designed to treat a flow of 2.5 mgd. The effluent soluble BOD from the basin averaged 450 mg/l with a volatile suspended solids level of approximately 850 mg/l.

In 1977, it was decided to expand and upgrade the pretreatment facilities to accommodate the increased loadings and produce an effluent with a soluble BOD level of less than 350 mg/l. Discussions with brewery personnel indicated that with increases in production and expansion of the brewery facilities, the average brewery wastewater flow could be expected to be 3.5 mgd with a BOD concentration of approximately 2,000 mg/l.

TABLE 2. SUMMARY OF BREWERY RAW WASTEWATER CHARACTERISTICS

Parameter(a)	Monthly Average Values					
	1976			1977		
	Min.	Avg.	Max.	Min.	Avg.	Max
BOD	1,011	1,509	2,103	945	1,378	1,777
SS	269	546	739	361	526	773
TKN	--	--	--	20	27.8	46
NH_3-N	4.1(c)	4.2(c)	4.3(c)	1.4	4.4	12
NO_3-N	3.8(c)	3.9(c)	4.1(c)	0.4	3.0	15.5
ALK	395(c)	405(c)	414(c)	209	320	402
pH, units	5.7	6.9	7.4	6.9	7.5	7.7

[a] All units are mg/l except as noted.

[b] Expressed as mg/l of C_2CO_3.

[c] Data shown for November 1976 and December 1976 only.

Prior to upgrading the treatment facilities, the operation of the existing pretreatment system was reviewed. The objective of this review was to define problems in the operation of the brewery pretreatment system so that solutions to these problems could be incorporated in the upgraded facility. A discussion of some of the operational problems associated with the treatment of brewery wastewaters is presented as follows.

OPERATIONAL CONSIDERATIONS

Significant variations in both the quantity and quality of brewery wastewaters result because of batch processing and the seasonal fluctuations in production schedules. Figure 2 presents the chronological variations of the average monthly BOD and suspended solids loading to the Elledge treatment plant from the brewing facilities. Peak production, as noted by increased loadings to the plant, was during April through August, which is consistent with historical data. These seasonal variations are significant in the operation of waste treatment facilities from the standpoint of:

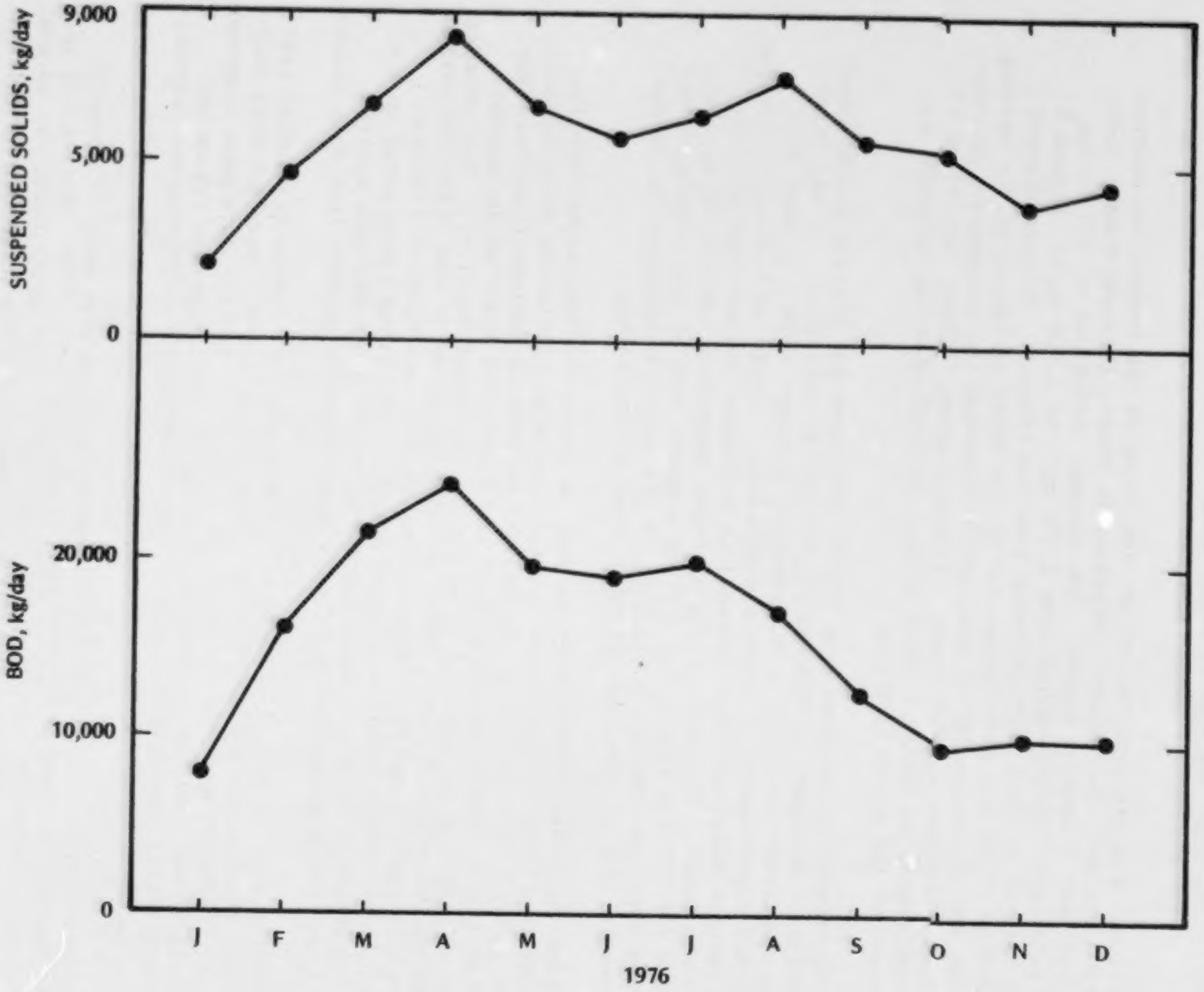


FIG. 2 MONTHLY VARIATION OF BREWERY WASTELOAD

1. Equalization must be provided or the facility must be sufficiently large to accommodate the peak loadings.

2. The high loadings increase oxygen demand on the treatment system during the summer months.

Significant diurnal load variations are found in the brewery wastewater. Figure 3 presents the diurnal variation in chemical oxygen demand (COD) observed over a 48-hour period. The diurnal variations of COD during this particular period ranged from 1,100 mg/l to 2,600 mg/l. Figure 4 shows typical diurnal flow patterns from the brewery. Extreme diurnal variations of pH are experienced due to the batch operation of the brewing process and the necessity of thoroughly cleansing the equipment with caustic wash solutions between brews. Figure 5 shows typical variations of the wastewater pH during a 24-hr period and indicates the severity and duration of the pH oscillations.

The wastewater as received from the brewery does not contain a sufficient quantity of nitrogen to accommodate biological oxidation. It is, therefore, necessary to supply a supplemental nitrogen source to meet the nutrient requirements of the microorganisms. Liquid agricultural nitrogen (30 percent total nitrogen content) is purchased and metered into the aeration basin. The cost of the nitrogen supplement amounts to approximately $36,000 per year. The varying organic load of the brewery wastestream requires constant monitoring of the nitrogen addition facilities to ensure that an adequate nitrogen level is maintained.

Problems have been experienced because of excessive discharges into the treatment system. Three major organic discharges including dextrose and corn syrup have occurred at the brewery because of equipment malfunctions and ruptured pipes. The largest of the discharges resulted in approximately 22,500 kg of dextrose entering the treatment facility. This organic load to the aeration basin caused a rapid depletion of the dissolved oxygen level in the pretreatment basin and subsequent reduction of treatment efficiency. This resulted in high organic loads being transferred to the plant proper with an ultimate deterioration of final effluent quality. It took approximately three days for the system to recover from this shock.

The discharge of oil and grease into the collection system is another problem. The oil and grease originate from the metal cans manufacturing facility. Although no inhibitions to the biological systems have been observed due to the oil and grease spills, fouling of the collection system and pumping facilities has occurred. This results in a large manpower expenditure in cleaning the transport facilities.

A frequently occurring problem encountered in the treatment of brewery wastewaters is that of foam on the aeration basins. Foam layers 4 - 5 in. deep have formed on the aeration basins and this is undesirable for several reasons. The foam rises and flows out and onto the ground surrounding the basins. The bio solids become entrapped in the foam and are also carried out of the basin. This causes unsafe conditions and presents a potential odor problem. Additionally, if the foam does not overflow the basins, the

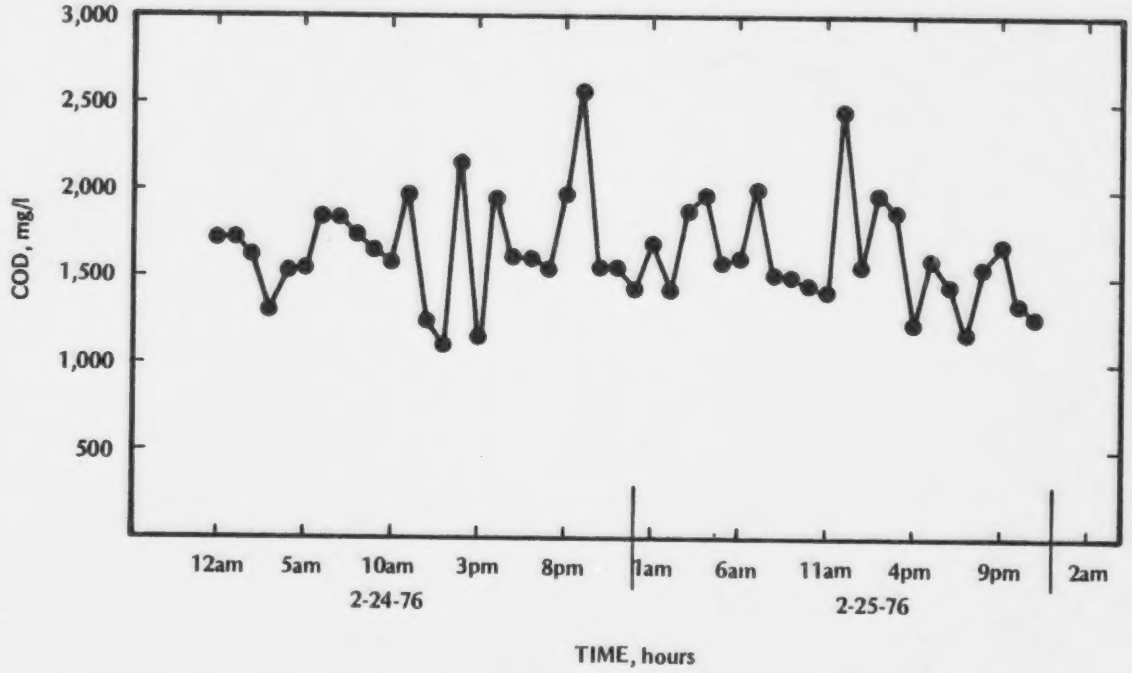
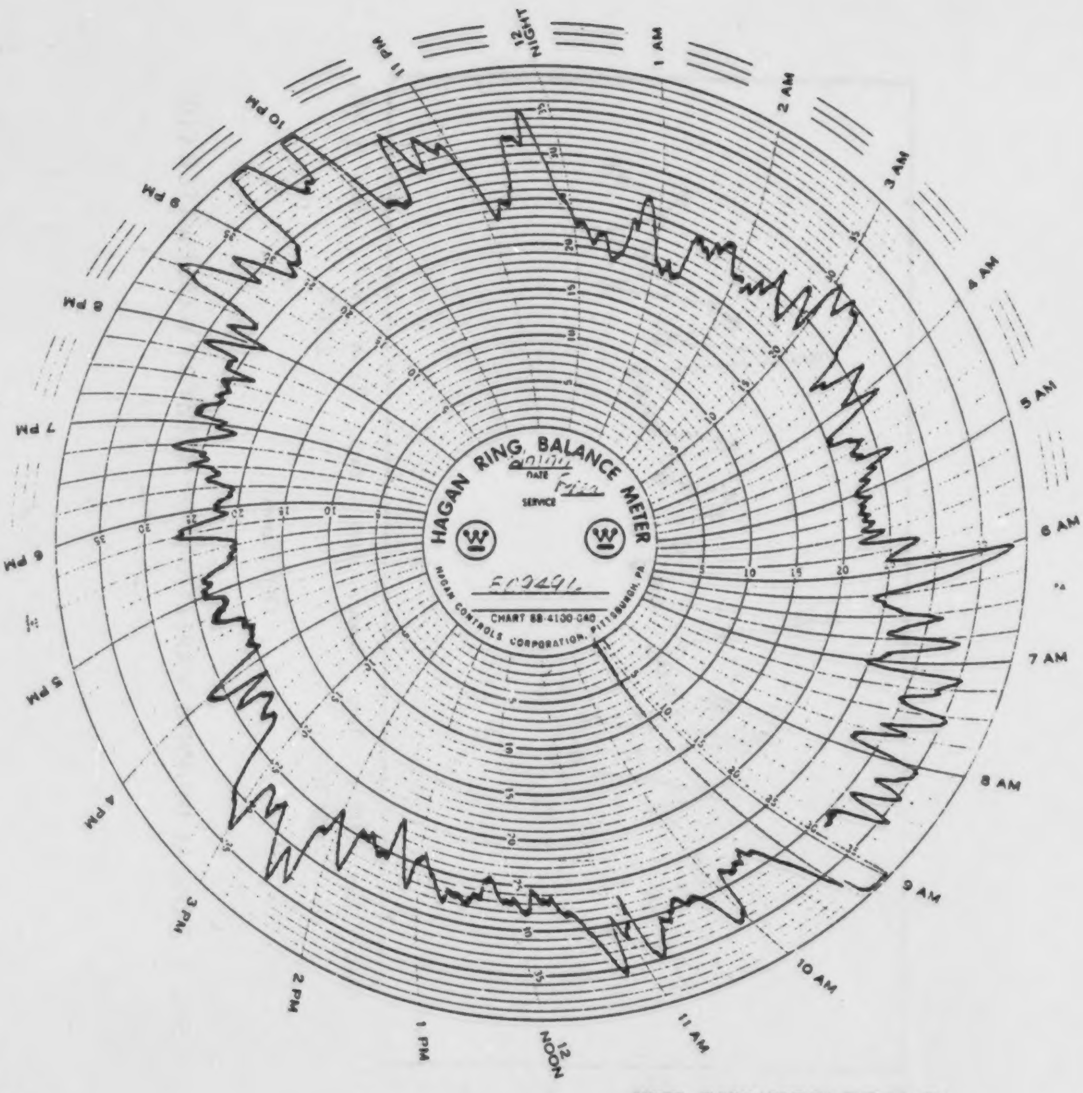


FIG. 3 TYPICAL DIURNAL VARIATIONS OF BREWERY WASTEWATER COD



NOTE: EACH UNIT ON THE GRAPH
REPRESENTS 1 mgd

FIG. 4 TYPICAL DAILY FLOW PATTERNS FROM THE BREWERY

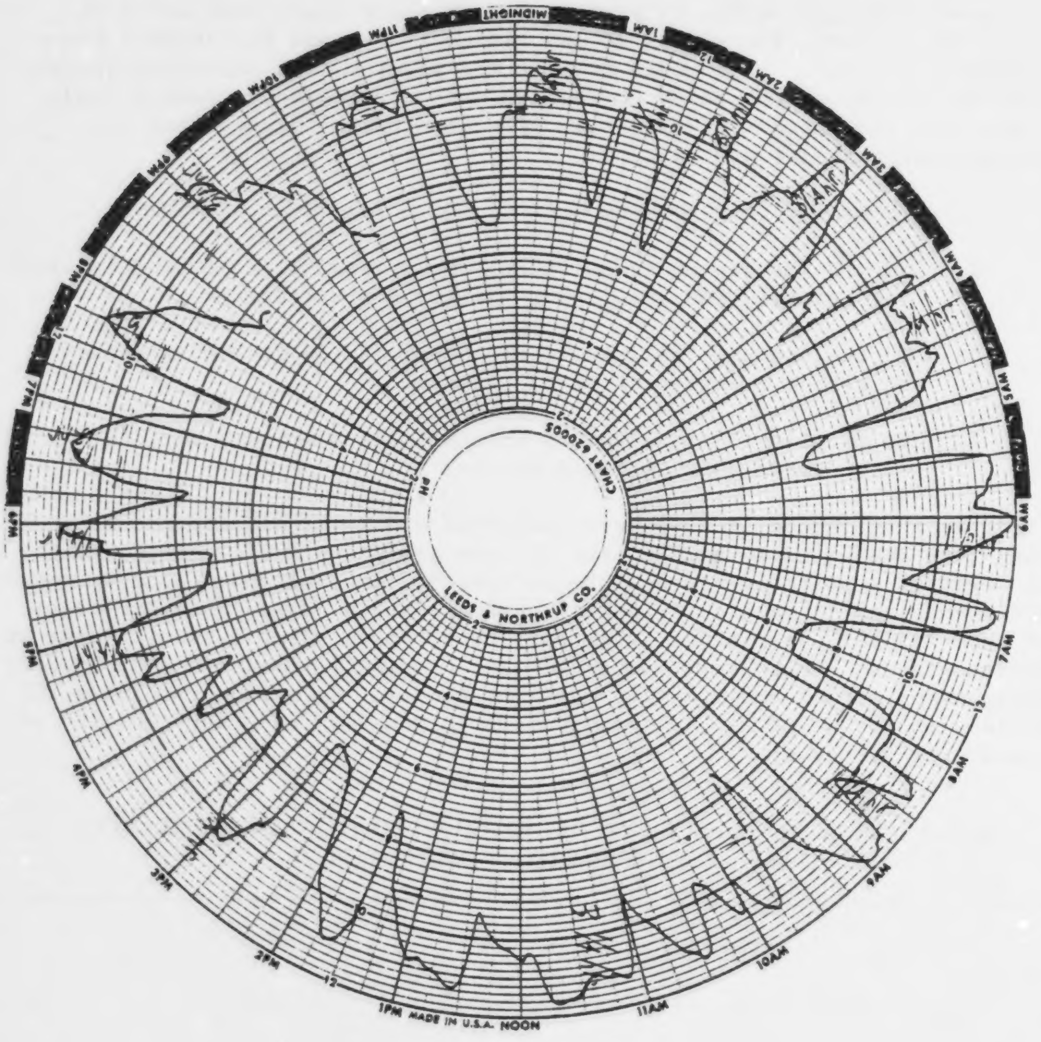


FIG. 5 TYPICAL DIURNAL pH VARIATIONS

solids have a tendency to accumulate and form crust layers on top of the foam, again resulting in odor problems.

SIGNIFICANT DESIGN CONSIDERATIONS

Increased loadings on the Elledge treatment plant again overloaded in the plant in 1976 ; therefore, it was decided to expand the brewery pretreatment process. This would relieve the plant of the increased brewery loadings and allow the plant to receive and accommodate increased loads from other industrial contributors. The objectives in upgrading the brewery pretreatment system were:

1. To reduce the incoming organic waste load from the brewery.
2. To provide capabilities within the system to dampen and equalize the quantity and quality of the brewery wastewaters.
3. To include the flexibility of operating the two-basin system in either a series or parallel mode.
4. To examine the feasibility of utilizing anaerobic digester supernatant as a nitrogen source.

Pilot aerated lagoon studies were performed and full-scale operating data were evaluated to develop the process design criteria and the use of digester supernatant as a nitrogen source. The results of these studies are summarized in Table 3. Table 4 presents the average characteristics of the digester supernatant. The results of the studies indicated that an aerated lagoon could provide high levels of organic removal. The digester supernatant proved an effective nutrient source. An effluent soluble BOD of less than 350 mg/l could consistently be achieved with the addition of digester supernatant.

TABLE 4. SUMMARY OF ANAEROBIC DIGESTER SUPERNATANT CHARACTERISTICS ARCHIE ELLEDGE WASTE TREATMENT PLANT

Parameter	Value
COD, total (mg/l)	14,891
Solids (percent)	1.70
Volatile Solids (percent)	0.80
NH_3-N (mg/l)	245.
Flow m^3	946.25

TABLE 3

SUMMARY OF PILOT PLANT PERFORMANCE

Parameter	Value [(a)]											
	Unit I[(b)]			Unit II[(c)]			Unit III[(d)]			Unit IV[(e)]		
	Influent	Basin	Effluent	Influent	Basin	Effluent	Influent	Basin	Effluent	Influent	Basin	Effluent
BOD, total	839		259	839		198	2,228		753	2,370		824
BOD, soluble	613		45	613		23	1,267		220	1,165		76
COD, total	1,269		1,055	1,269		857	5,580		2,606	4,870		3,419
COD, soluble	1,032		183	1,032		167	2,063		467	1,975		295
SS	559		761	559		807	3,200		2,435	4,278		4,185
VSS	253		419	253		475	1,878		1,337	2,030		2,544
SS (ZSV Supernatant)	--		373	--		188	--		367	--		265
VSS (ZSV Supernatant)	--		265	--		133	--		240	--		86
TKN, total	55		--	55		--	213		31	279		--
TKN, soluble	--		--	--		--	--		29.5	--		22
NH_3-N	19		23	19		26	45		13	55		16
pH (units)	7.3	8.0	7.9	7.3	8.1	7.9	7.0	7.8	7.8	7.1	7.8	7.9
MLSS		872			863			3,348			4,641	
MLVSS		513			516			1,966			2,673	
D. T. days		1.21			2.31			1.10			0.99	
O_2 Uptake, (mg/1 - min)		0.28			0.23			0.41			0.29	
Temperature, °C		20			20			20			20	
F/M (g/BOD/g MLVSS - day)		1.35			0.70			1.03			0.90	
D.O.		5.4			5.4			3.0			3.2	
Averaging Period	2/1 to 23/77			2/1 to 23/77			3/1 to 15/77			3/1 to 15/77		

a) All units are mg/1 except as shown.

b) Unit at one-day detention time.

c) Unit at two-days detention time.

d) Unit at one-day detention time, with 9 percent supernatant (based on influent flow).

e) Unit at one-day detention time, with 13 percent supernatant (based on influent flow).

Tests were conducted to determine the rate of oxygen transfer into the brewery wastewater relative to the oxygen transfer rate into tap water (alpha tests). Several series of alpha tests were performed through the course of the study. These results are summarized in Table 5. These values, 0.6 to 0.7, are considered reasonable and were used for design.

TABLE 5. SUMMARY OF OXYGEN TRANSFER ANALYSES

Sample Location and Date	Test Speed RPM	Alpha Factor[a]
Basin Effluent (March 1976)	150	0.52
	225	0.15
	300	0.33
Basin Effluent (March 1977)	100	0.66
	200	0.67
	288	0.64
Basin Influent (March 1977)	100	0.48
	200	0.56
	288	0.58

[a] All values corrected to 20°C.

The microorganisms utilize oxygen for biological respiration. For brewery waste treatment, (approximately 2.0 to 5.0 g O_2/g basin volatile solids-day is required). This is very high when compared to rates for a typical activated sludge system of between 0.1 to 0.8 g O_2/g basin volatile solids-day.

These two factors, low transfer rates and high oxygen uptake rates, result in a large horsepower input to the basin, approximately 270 hp/mil gal of basin volume. Typical activated sludge horsepower levels range from 100 to 150 hp/mil gal of basin volume.

DESIGN CONSIDERATIONS FOR OPERATIONAL FLEXIBILITY

Utilizing the results from the bench-scale tests, and data gathered from the operation of the full-scale system, a process design was developed for the proposed expansion. The design summary for the expanded facilities is presented in Table 6.

Figure 6 presents a schematic illustration of the expanded facilities employed for the pretreatment of the brewery wastewaters. Basin 1 was first placed on line in 1971 and Basin 2 was put into service in October 1977. Total installed horsepower for both basins is 900.

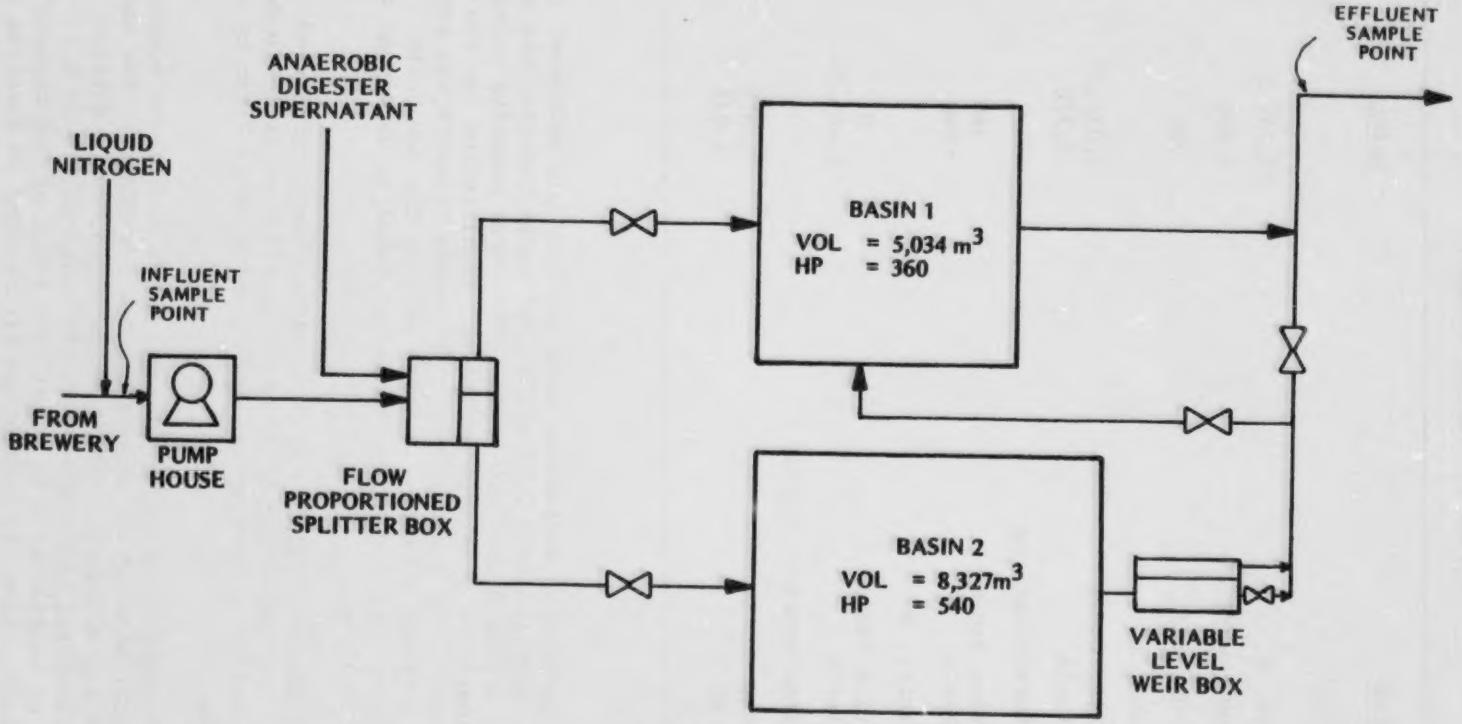


FIG. 6 SCHEMATIC ILLUSTRATION OF BREWERY PRETREATMENT FACILITIES

TABLE 6. DESIGN SUMMARY

Parameter	Value
AERATED LAGOON	
Design Flow, m^3	13,247.5
Influent BOD, mg/l	2,000
Effluent BOD, mg/l	350
Basin Volume, m^3	
Existing Basin	5,034.05
New Basin	7,570
Aeration Horsepower, hp	
Existing Basin	360
New Basin	540
Surge Capacity, m^3	
Existing Basin	0
New Basin	2,460.25
Nitrogen Requirements, kg/day	
Maximum	1,314
Average	1,026

The problem of fluctuating wastewater flow and load was addressed in the process design. Approximately 0.65 mil gal of surge capacity was incorporated into the design of the new basin. The surge capacity calculations were predicated on providing additional equalization for the activated sludge basin in the plant proper. The surge capacity was achieved by constructing a variable level discharge weir in the new basin. Using high-speed, floating aerators allows the water level to be varied approximately 2.5 feet (0.65 mg).

In the design of the new facilities, flexibility was incorporated to allow the operation of the two basins in either a parallel or series mode. Basin 1 is operated on a flow-through basis, while Basin 2 can be operated at varying levels.

It was decided to utilize digester supernatant as a nitrogen source. Utilizing the digester supernatant offers several advantages. The need to purchase ammonia was eliminated resulting in a $35,000/yr savings. The supernatant characteristically has pH in the range of 6.5 to 6.8. This slightly acidic pH coupled with an alkalinity value of approximately 2,000 mg/l, as $CaCO_3$, helps to buffer the fluctuating pH received from the brewery. Additionally, the basin alkalinity as $CaCO_3$ has increased from approximately 225 mg/l to approximately 450 mg/l. This affords a much greater degree of protection from pH upsets. A pumping station was constructed and attendant piping installed (approximately 1,080 m at 20-cm diameters).

The causes of foaming were evaluated and it was determined that the foaming phenomenon results because of:

1. The high agitation levels within the basin (approximately 270 hp/mil gal.
2. Large volume of caustic wash solutions used at the brewery.
3. The foaming nature of the beer product itself. Operating experience has found that the foam can best be controlled with the use of commercially available defoaming agents.

The problem of oil and grease discharges was resolved through the cooperation of both the City and the brewery. The brewery has implemented pretreatment to capture oils.

TREATMENT PLANT PERFORMANCE

The new basin has been on stream since October 1977. Several mechanical difficulties prevented full-scale operation prior to February 1978. The first several weeks of operation are encouraging. Figure 7 presents a chronological summary of various operational parameters. These data indicate that the basin is consistently producing an effluent with a soluble BOD level of less than 350 mg/l. Normally, effluent soluble BOD is in the range of 200 mg/l. These data reflect parallel operations of the two basins. Operation in a series mode has not been initiated.

The treatment of brewery wastewaters in a municipal waste treatment plant presents some particular problems that must be addressed through design and operation of the facility. The City of Winston-Salem has addressed this problem and has developed a program to successfully treat brewery wastes.

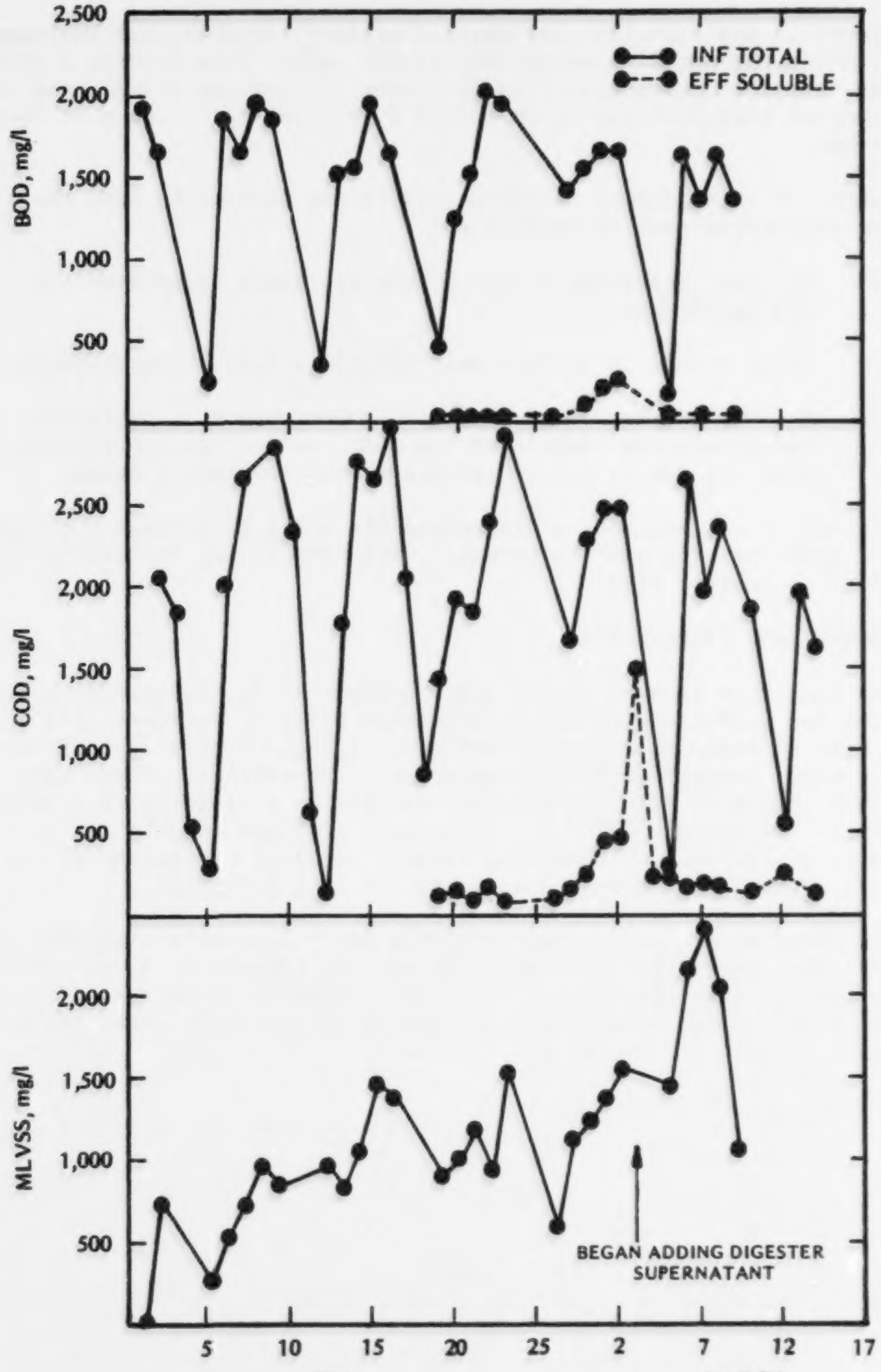


FIG. 7 CHRONOLOGICAL VARIATION OF PRETREATMENT SYSTEM PERFORMANCE

PHOSPHORUS REMOVAL AND DISINFECTION OF MEAT PACKING LAGOON EFFLUENT

by

Richard T. Beaupre'* and Milton D. Redick*

INTRODUCTION

In order to comply with EPA and the State of Michigan wastewater effluent limitations, the Peet Packing Company of Chesaning, Michigan, contracted with Capitol Consultants, Inc., of Lansing, Michigan, for an engineering study to determine alternatives for the upgrading of existing anaerobic-aerobic lagoon facilities.

Preliminary design basis and cost estimates were generated for seven alternatives for additional BOD, SS, ammonia, and phosphorus removal as well as disinfection. Based on modified discharge requirements by the Michigan Department of Natural Resources, it was decided to proceed with design and construction of phosphorus removal and disinfection facilities. Phosphorus removal is to be attained with chemical addition and clarification. Due to high ammonia levels of the wastewater, disinfection with chlorine dioxide was chosen in order to reduce chlorine demand and to reduce the formation of potentially harmful chlorine compounds. Construction of the facility is nearing completion at this time.

BACKGROUND

The Peet Packing Company, Chesaning, Michigan, is a meat processing plant which slaughters and processes an average of 1,050 hogs a day into fresh and smoked meat products. The current employment at the plant is approximately 400 persons. The plant is located just north of the Village limits of Chesaning, Michigan, and adjacent to the Shiawassee River, a tributary to Lake Huron.

The principal meat products at the plant are fresh and smoked hams, sausages, and luncheon meats. Raw beef is purchased from outside sources for inclusion in these products. Additional daily processes are the rendering of fat into edible lard, and the drying of blood into an agricultural product. By-products consisting of all hog-viscera, condemned carcasses, parts of bones, and lard rendering refuse are shipped to an independent renderer. Hair and holding pen manure are also hauled from the plant.

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*Capitol Consultants, Engineers, Inc., Lansing, Michigan

The wastewater from Peet Packing Company varies greatly in both volume and character throughout a normal operating day. Major wastewater streams are hog and carcass rinse water from the kill floor, chill sprays from the cut floor, scald tank dumping, sanitary sewage, boiler blow-down, compressor cooling water, and plant cleanup chemicals and water. The majority of blood is captured during the sticking operation and pumped to a dryer. The steam condensate from the dryer contains blood residue which also adds to the wastewater strength.

Original Wastewater Treatment Facilities

The original wastewater treatment facilities consisted of an anaerobic and two aerobic ponds operated in series and with continuous discharge. The ponds were constructed in 1967 and designed on an expected BOD_5 loading of 750 kg (1,650 lbs.) per day and a flow of 1,285 m^3/d (340,000 gpd)(1). The plant currently discharges approximately 640 m^3/d (170,000 gpd) to the Shiawassee River in South Central Michigan.

Raw wastewater is collected at a large sump and pumped to the anaerobic lagoon, a distance of approximately 245 m (800 feet). The lagoon is a clay lined 3.7 m (12 feet) deep pond, with dimensions at the surface of 46 x 46 m (150 x 150 feet), and with walls sloped 2 horizontal to 1 vertical. The volume of the pond is 3,855 m^3 (1,020,000 gal.); at a plant flow of 640 m^3/d (170,000 gpd), the average detention time is 6 days. A heavy layer of fat and scum accumulates on the pond surface and maintains anaerobic conditions; the layer also helps control odor and heat loss. The anaerobic lagoon has two withdrawal pipes which empty to a wet well pumping station through a siphon which maintains a constant pond depth. Wastewater is pumped from the station a distance of 660 m (2,180 feet) to the aerobic lagoons.

The aerobic lagoons are 1.5 m (5 feet) deep clay lined ponds with a total surface area of 5.9 hectares (14.3 acres). The walls have a slope of 3 horizontal to 1 vertical; freeboard at a 1.5 m (5 foot) depth is 0.9 m (3 feet). The volume of the ponds is 83,000 m^3 (22,000,000 gal.); the average detention time at a plant flow of 640 m^3/d (170,000 gpd) is 130 days. The aerobic ponds were designed for an average BOD_5 loading of 33.6 kg/hectare/day (30 lbs./acre/day), or 196 kg/day (430 lbs./day). Wastewater from the aerobic ponds flows by gravity a distance of 460 m (1,500 feet) to the Shiawassee River.

Lagoon Treatment Efficiencies

Table 1 is a summary of testing data from 1973 through 1977. Raw wastewater samples, composited during the slaughtering operation, were collected by Peet Packing and tested for BOD_5 once a week from 1969 through July of 1975. The results of these tests vary widely from BOD_5's of 800 mg/l to over 10,000 mg/l. Raw wastewater sampling is very difficult, however, in that large pieces of fat or tissue cannot adequately be accounted for, nor do grab samples account for lower flows and strength during non-slaughtering hours and weekends. The figure of 2,000 mg/l is the best estimate of the overall average weekly raw wastewater strength.

Grab samples of anaerobic lagoon effluent were also tested on a weekly basis by Peet Packing. This data showed the lagoon effluent BOD_5 to normally vary from 150 mg/l to 700 mg/l, with peaks of up to 6,700 mg/l when the blood dryer was not in operation. The temperature of the effluent varies between 29° C. (85° F.) in the summer and 14° C. (57° F.) in the winter. The pH varies from 6.3 to 7.5 with most readings below 7.2. The data collected indicates a typical reduction in BOD_5 of from 80% to 85% through the anaerobic lagoon. References (2), (3), and (4) show typical removal rates of 80% at other meat packing anaerobic lagoons. Of significant importance is the increase in ammonia content over the raw wastewater due to the decomposition of meat pieces and the conversion of organic nitrogen.

The aerobic lagoon effluent quality has been defined by weekly sampling of BOD_5 prior to 1975, and in addition, weekly sampling of suspended solids, total phosphorus, ammonia as N, and oil and grease since that time. The data shown in Table 1 are presented in time periods to demonstrate the influence of periods of shut-down of the blood dryer and the freezing over of the aerobic lagoons. During periods of blood dryer shut-down all blood is included in the wastewater stream and lagoon loadings are increased by a factor of ten. In order to alleviate this large overloading, the company has recently made provisions to haul blood from the plant when the dryer requires repair. Figure 1 is a plot of average monthly BOD_5 and the data indicates a significant deterioration of quality during winter months; however, during all of the past winters, the blood dryer has not been in operation for periods of up to a month, and during January and February of 1975, the anaerobic lagoon was dredged out. Thus the freezing of the ponds appears to have a significant influence on BOD_5; however, the extent is not known.

The aerobic ponds have typically produced a BOD_5 reduction of from 60-90%, with the 90% rates occurring when the ponds were at normal loadings of 34 kg/ha/day (30 lbs./acre/day) or less. The overall average loading of the aerobic ponds, however, has been 40 kg/ha/day (36 lbs./acre/day) with peaks up to 740 kg/ha/day (660 lbs./acre/day) when the blood dryer was shut-down. In addition to hauling blood when it cannot be dried, the plant has also been attempting to install a hydrasieve screen to eliminate pond overloading. The six month period of from June, 1976 to December, 1976, illustrates an average final effluent quality of 38 mg/l BOD_5 and 70 mg/l S.S. is achievable. These concentrations would result in an average discharge to the River of 25 kg/day (54 lbs./day) BOD_5 and 45 kg/day (99 lbs./day) S.S. at 640 m^3/d (170,000 gpd).

Figure 2 is a plot of average monthly phosphorus concentration based on weekly sampling, and fecal coliform counts based on monthly sampling. The average monthly phosphorus concentrations follow a nearly identical pattern as the effluent BOD_5 shown in Figure 1, except with a less dramatic variation. The variation in phosphorus may, however, be due to algae uptake and release. Fecal coliform counts have been below the required July 1, 1977 NPDES permit levels much of the time, but appear to jump higher coincidentally with the blood evaporator shut-down and initial heavy BOD discharge.

TABLE 1
SUMMARY OF WASTEWATER QUALITY DATA
JULY, 1973 TO MAY, 1977
PEET PACKING COMPANY, CHESANING, MICHIGAN

Sample	Sampling Period	BOD$_5$ mg/l	S.S. mg/l	Phos. mg/l	NH$_3$ mg/l	Fecal Coliform #/100 ml	Flow	
							m^3/d	mgd
Raw Waste-water	7/73-7/75	2,000	--	19*	7*	--	--	--
Anaerobic Lagoon Effluent	7/73-7/75	360	--	25*	55*	--	--	--
Aerobic Lagoon Effluent	7/73-7/75	163	--	25*	55*	2,400**	720	0.19
	8/75-12/75	36	81	16	61	800	680	0.18
	1/76-5/76	182	101	24	75	2,900	640	0.17
	6/76-12/76	38	70	21	48	300	490	0.13
	1/77-5/77	251	102	32	69	40	640	0.17

Fecal Coliform Samples: 1 grab per month
Remaining Samples: 1 grab per week

*One sample.
**Five samples.

Effluent Limitations

The effluent limitations for the Peet Packing Company were determined based on the most stringent of two criteria: the water quality standards of the Michigan Department of Natural Resources and the EPA "Meat Products Point Source Category Effluent Guidelines and Standards"(5). The Peet Packing Company is categorized as a "High-Processing Packinghouse". The water quality standards require an average BOD$_5$ of less than 36 kg/day (80 lbs./day) and 80% phosphorus removal; EPA limitations based on LWK (live weight killed) resulted in limitations of BOD$_5$ of less than 36 kg/day (80 lbs./day), T.S.S. of less than 46.9 kg/day (104 lbs./day), fecal coliform counts of less than 400/100 ml, and oil and grease of less than 20 kg/day (44 lbs./day) with daily maximum limits less than twice that of the average. The original effluent limitations also included a maximum ammonia discharge of 8 mg/l during the period May 1 through October 31, with a pH limitation between 6.0 and 7.5. The ammonia limitation was later dropped by the Michigan DNR.

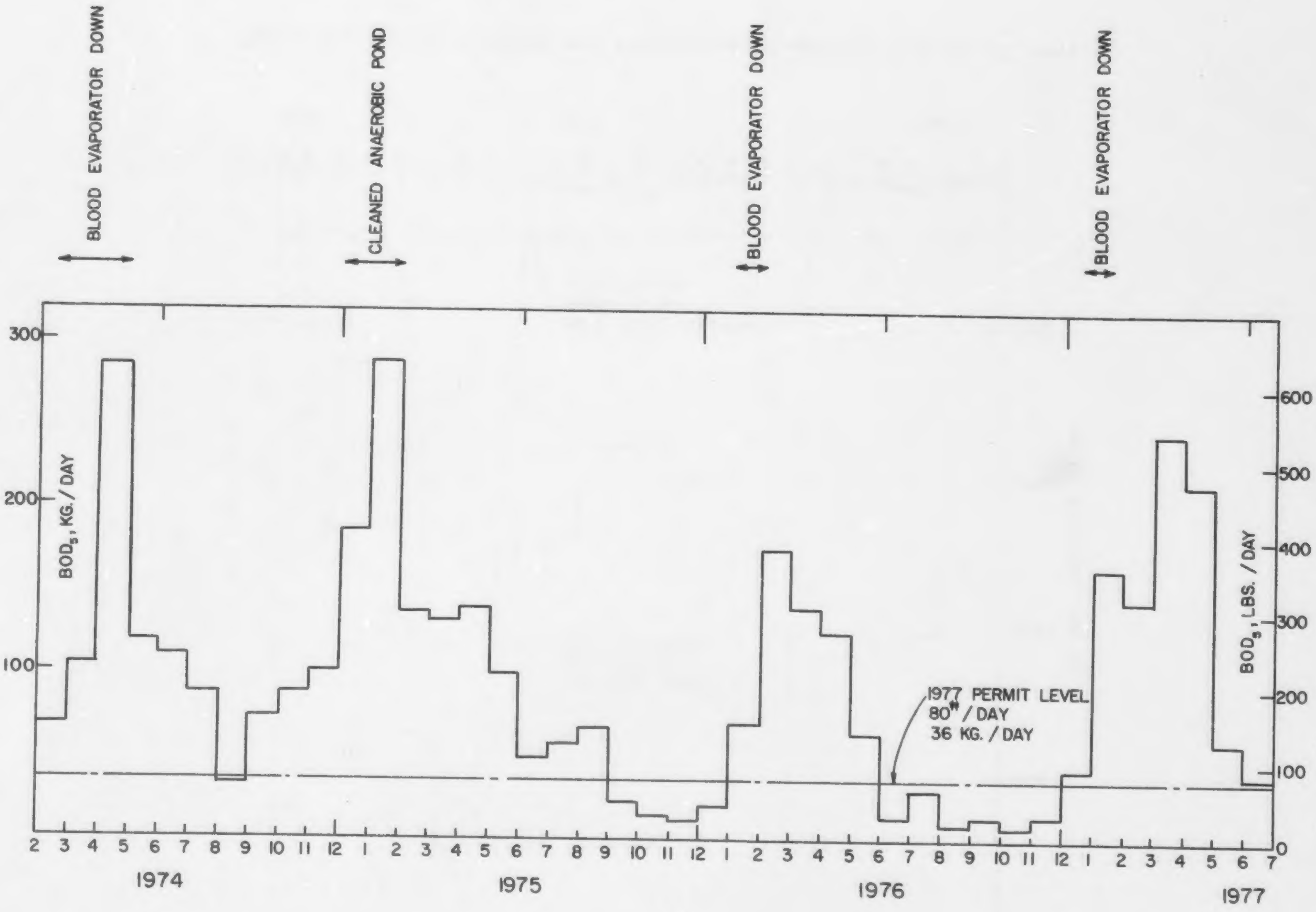

Figure 1. BOD_5 of anaerobic lagoon effluent.

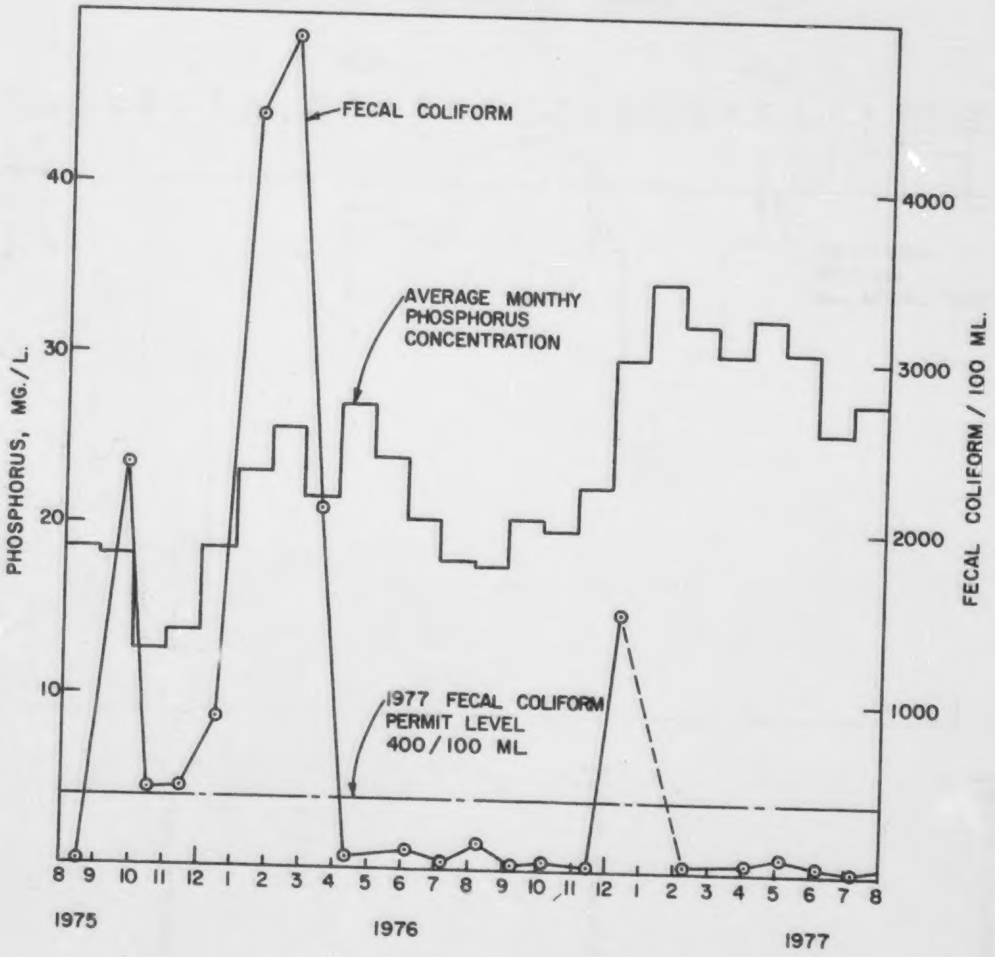

Figure 2. Fecal coliform and phosphorus of aerobic lagoon effluent.

WASTEWATER TREATMENT ALTERNATIVES EVALUATED

Preliminary design basis and cost estimates were generated for seven alternatives for upgrading the anaerobic-aerobic lagoons at the Peet Packing Company. The alternatives were to provide additional BOD, S.S., ammonia, and phosphorus removal, as well as disinfection. All of the alternatives evaluated utilized biological treatment for BOD, S.S. and ammonia removal. The most severe limitation for treating the wastewater was the ammonia removal requirement. Ammonia can be converted to nitrate by nitrifying organisms but their activity is hindered by low temperature and substantial BOD reduction must take place prior to their becoming effective(6).

The first four alternatives included complete treatment at the Peet Packing Company utilizing the existing anaerobic lagoon with the aerobic lagoons used as a backup system. Additional biological treatment after the aerobic lagoons was not considered because it was felt the very low discharge temperatures of 2° C. (35° F.) during the winter and 7° C. (45° F.) during April would inhibit establishment of ammonia removal prior to the May 1st requirement. The fifth alternative considered pretreatment following the anaerobic lagoon with discharge to the Village of Chesaning Municipal Wastewater Treatment Facility.

The design basis for treatment after the anaerobic lagoon was as follows:

Flow	1,134 m^3/d (0.3 mgd)
D.O.	0 mg/l
BOD_5	500 mg/l
S.S.	300 mg/l
NH_3-N	50 mg/l
P	25 mg/l

The sixth and seventh alternatives were to utilize both the anaerobic lagoon and aerobic lagoons. The sixth alternative was to provide additional storage for intermittent discharge during the winter months only, when river flows are greater and 80% ammonia removal was required, rather than removal to a level of 8 mg/l. The seventh alternative was land application with border strip irrigation.

The major design parameters, capital cost and annual cost for each of the alternatives are summarized as follows. The capital cost estimates were for 1976, and include engineering and contingencies. The annual cost estimates include amortization of the capital cost at 8% interest over 20 years, labor, power, chemicals, testing, sludge handling and maintenance.

Alternative 1 - Rotating Biological Disc

This system required 55,800 m^2 (600,000 $ft.^2$) of media on 6 shafts, six 5 HP drives, fiberglass covers for the shafts, a pre-aeration basin with 4 hours detention time to restore D.O., a clarifier, a chlorine contact chamber, an aerobic sludge digester, and a control building with chemical storage. Some of the advantages of a rotating disc system are low power cost, ease of operation and low maintenance cost. The total estimated cost of the system was $767,000, with a total annual cost of $136,200.

Alternative 2 - Extended Aeration Activated Sludge

An extended aeration system required a 2,270 m^3 (600,000 gal.) circular aeration basin, three 50 HP compressors, two clarifiers, a chlorine contact chamber, an aerobic sludge digester, and a control building with chemical storage. The aeration unit required 48 hours detention time and a solids retention time greater than 10 days in order to achieve nitrification. In order to achieve long solids retention times, a high solids recycle was required for the first clarifier which would not be conducive for phosphorus removal. Therefore, a separate clarifier was proposed for phosphorus precipitant settling. A dome cover was also proposed to minimize heat loss and control odor problems. The total estimated cost of the system was $769,600, with a total annual cost of $156,500.

Alternative 3 - Oxidation Ditch

An oxidation ditch system required a 2,840 m^3 (750,000 gal.) looped trapezoidal channel, two 5.5 m (18 foot) long rotor aerators with a 30 HP drive for each, two clarifiers, a chlorine contact chamber, an aerobic sludge digester and a control building with chemical storage. The oxidation ditch was to provide a minimum of 48 hours detention time and 10 days solids retention time. The advantage of the oxidation ditch system was a lower capital cost and ease of maintenance; however, odor control would be more difficult, and lower wastewater temperatures would result. The total estimated cost of the system was $590,000, with a total annual cost of $118,200.

Alternative 4 - Pure Oxygen Activated Sludge

A pure oxygen system required a closed chamber, 15 m (50 feet) square and 3-5 m (10-16 feet) deep, containing a BOD_5 removal cell with a 7-1/2 HP mixer, a clarification cell, an ammonia removal cell with a 5 HP mixer, and a second clarification cell for phosphorus removal. The system also required a pre-aeration tank, an aerobic digester, a chlorine contact chamber, and a control building with chemical storage. Pure oxygen would be supplied from a liquid oxygen storage tank which would require filling every 2 months by a truck delivery. The major advantage of a pure oxygen system is the limited space required. The total estimated cost of the system was $764,600, with a total annual cost of $158,100.

Alternative 5 - Pretreat and Discharge to Municipal Wastewater Treatment Plant

The discharge of industrial waste to a municipality is governed by EPA "Pretreatment Standards"(7), which require that an industry remove any waste pollutant which would not be removed by the municipality. Since the new Chesaning plant did not have design capacity for ammonia removal, the high ammonia content of Peet Packing could be considered "incompatible" and require removal to a level acceptable for direct discharge to the River (Section 128.133). Discharge to the Village therefore required an oxidation ditch, one clarifier for solids retention, an aerobic sludge digester, a control building, modification of the existing pumping station, and 823 m (2,700 feet) of 20 cm (8 inch) force main. The total estimated cost of the Peet Packing system was $534,300, with a total annual cost of $140,000. However, the Chesaning plant also required expansion to accommodate the increased waste load. The Village of Chesaning, at that time, had received an EPA Step 3 grant for 75% of the project cost and had just taken construction bids for major treatment plant expansion which did not include capacity for the Peet Packing Company. The Village therefore would have had to either abandon their grant and begin Step 1 and Step 2 planning anew or pay for the additional expansion with 100% local financing. It was therefore decided it would be too costly in terms of rewriting the facilities plan, redesigning the plant and implementing industrial cost recovery, to proceed with joint treatment.

Alternative 6 - Additional Treatment with Seasonal Discharge

This system required an additional 4.6 hectares (11 acres) of aerobic ponds plus an oxidation ditch, two clarifiers, an aerobic digester, chlorine contact chamber, and a control building with chemical storage. The total cost of the system was $734,800, with a total annual cost of $139,400.

Alternative 7 - Land Disposal--Border Strip Irrigation

The border strip irrigation system required an additional 2.5 hectares (6 acres), 3.7 m (12 foot) deep storage pond for winter storage and 21 hectares (50 acres) of irrigation cells plus an additional 61 m (200 ft.) border for isolation. The irrigation cells would receive 5 cm (2 inches) of wastewater per week over 6 months of the year. Each of 74 bermed cells, 15 x 183 m (50 x 600 feet), would be flooded at 3.8 m^3/min. (1,000 gpm) for approximately 30 minutes once a week. Alfalfa hay would be grown on the land for nutrient removal and crop recovery income.

The design basis for the land disposal system was:

Flow	760 m^3/d (200,000 gpd)
BOD_5	60 mg/1
S.S.	90 mg/1
NH_3-N	50 mg/1
P	25 mg/1

A series of monitoring wells were anticipated to ensure that the proposed application rates would not result in nitrate contamination of the ground water.

An initial hydrogeological investigation of existing well logs in the area indicated a site adjacent to the existing lagoons suitable for such a system(8). Initial cost estimates also showed the alternative to be the most economical. A site study was therefore initiated which showed a clay layer 1.2-1.4 m (4-4.5 feet) below the surface with perched water at 0.9 m (3 feet) or less below the surface indicating poor drainage(9). A clay layer is advantageous in a land disposal system as it protects the ground water below it from possible contamination; however, a minimum of 2.4-3 m (8-10 feet) is needed above the clay to provide good drainage and bacterial reduction of the wastewater. The proposed site was therefore unacceptable and the sand fill necessary to make the site acceptable made the cost totally prohibitive. In addition, an alternate site within 3.2 km (2 miles) of the aerobic lagoons was not apparent.

WASTEWATER TREATMENT RECOMMENDED

The initial indications of the study were that land application would be the most advantageous alternative. After further hydrogeological investigation showed the site to be unacceptable, the oxidation ditch alternative became the most cost-effective solution for BOD, S.S., and ammonia reduction.

Following completion of the initial study, the NPDES permit was modified in part in that the ammonia removal requirement was deleted. The revised permit still required upgrading of the existing lagoon facilities to provide 80% phosphorus removal and disinfection. Further removal of BOD_5 and suspended solids was also required. Since BOD and S.S. discharge appeared to reflect breakdowns of the blood evaporator and a raw waste "Hydrasieve" was not yet in use, it was felt that significant improvements in the BOD_5 and suspended solids levels of the final effluent could be achieved by operation of the screen and by hauling blood to another suitable disposal facility during periods of repair to the blood evaporator.

Thus the proposed system to meet the July 1, 1977, effluent limitations was phosphorus removal by chemical addition and clarification, and disinfection by chlorine. This system would treat the effluent from the existing aerobic lagoons and discharge to the River by gravity. A flow schematic is shown in Figure 3.

The system was to consist of a 9.2 m (30 foot) diameter clarifier with a center flocculation zone, a chlorine contact tank, a sludge storage tank, chemical storage and feed equipment and a control building. The system was to have capability for the addition of either alum or ferric chloride in conjunction with a polymer.

It was anticipated that 80 to 90% of the phosphorus could be removed along with up to 60% of the algae, 50% of the BOD_5, and 50% of the suspended solids. Sludge storage would be provided and sludge would periodically (2-3

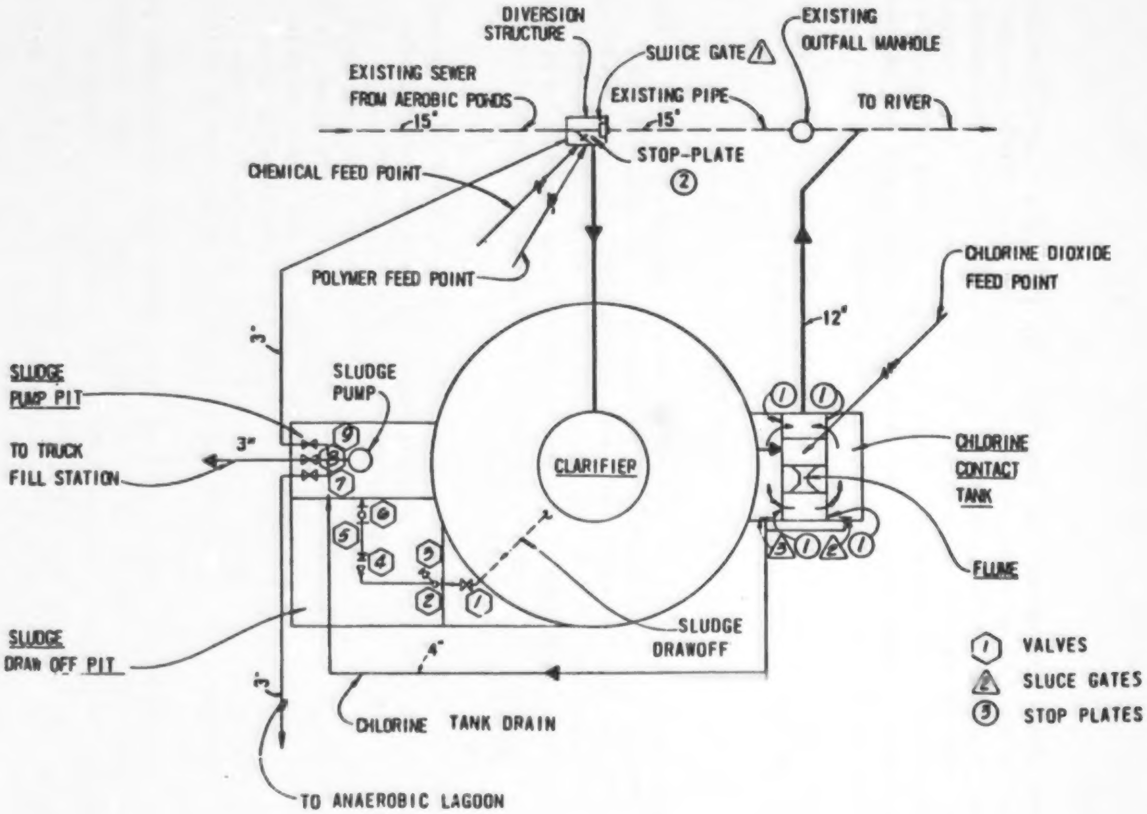

Figure 3. Process flow schematic for phosphorus removal and disinfection.

times a week) be removed by tanker truck and spread on farmland. The estimated cost of the facility was \$226,000, with an annual cost, including amortization, of \$55,000.

PROCESS DESIGN

Phosphorus Removal

Phosphorus removal from wastewater by chemical addition and clarification has become common at municipal wastewater plants throughout Michigan and other Great Lakes States. Phosphorus removal following lagoon treatment, however, has not been practiced extensively as it has not yet been required of small municipalities with lagoons. However, pilot studies for the City of Ludington, Michigan, demonstrated that similar design bases can be used for lagoon removals as for secondary biological treatment(10).

The precipitation reaction of phosphorus with any metal ion is similar to that of aluminum ion which can be expressed as follows:

$$Al^{3+} + PO_4^{3-} \longrightarrow AlPO_4 \downarrow$$

which gives a mole ratio of Al:P of 1:1 or a weight ratio of 0.87:1. However, the reaction and physical settling is dependent on interferring reactions, coagulation requirements, pH, and temperature, which necessitate chemical addition in excess of the 1:1 mole ratio of Al:P for efficient removal. The results of published studies of phosphorus removal with alum indicates that 80% phosphorus removal typically requires a mole ratio of between 1.5 and 2.3(11)(12)(13)(14)(15)(16).

The chemicals used in phosphorus removal usually provide ions of aluminum or iron, or calcium. Aluminum ion is usually supplied by aluminum sulfate (alum), $Al_2(SO_4)_3 \cdot 14H_2O$, or by sodium aluminate, $Na_2Al_2O_4$ or $NaAlO_2$. Iron is usually supplied by ferric chloride, $FeCl_3$, or ferrous sulfate, $FeSO_4$ or ferric sulfate, $Fe_2(SO_4)_3$. Calcium ion is usually supplied by lime, $CaOH_2$ or CaO. Waste alum sludge from water treatment plants and waste pickle liquor from steel production have also been used for considerable cost reduction. Alum was chosen to be used at Peet Packing because of its availability and because it is somewhat less corrosive than ferric chloride.

Polymer addition can enhance coagulation of the phosphorus precipitate and thus increase removal efficiency. Optimum dosages appear to vary greatly with the type of polymer used and wastewater characteristics, dosages between 0.2 and 1.0 mg/l are common. A flocculation system will also enhance the coagulation of the phosphorus precipitate with velocity gradients of 50 $sec.^{-1}$ typical.

The settling equipment for phosphorus removal at Peet Packing includes a 9.2 m (30 foot) diameter clarifier with a 3 m (10 foot) side water depth, a 2.6 m (9 foot) center flocculation well with a variable speed mechanical turbine type flocculator, sludge collector and surface skimmer arms, scum box, weirs and baffles. A control building houses a 18.9 m^3 (5,000 gal.) chemical (alum) storage tank, a .49 m^3/d (130 gpd) diaphragm type chemical feed pump, a .57 m^3 (150 gal.) polymer storage tank with wetting funnel, a mixer, and a .17 m^3/d (45 gpd) diaphragm type polymer feed pump. A non-potable water pump recycles clarified effluent for dilution water for both the alum and the polymer.

A telescoping valve allows withdrawal of clarifier sludge to a thickening tank from which a second telescoping valve can be used to decant the supernate back to the clarifier. Thickened sludge can then be transferred to a submersible pump sump from which it can be recycled back to the clarifier, pumped to a truck fill station, or pumped back to the anaerobic lagoon. Additional related equipment provided includes a 10 cm (3 inch) flume for flow measurement and recording, and a flow proportional composite sampler.

The typical dosage requirements for 80% phosphorus removal were estimated assuming a 1.7 mole ratio of Al:P, a 20 mg/l influent phosphorus concentration, and a flow of 756 m^3/d (200,000 gpd) as follows:

$$\frac{756\ \text{m}^3}{\text{day}} \times \frac{1{,}000\ \text{kg}}{\text{m}^3} \times \frac{20\ \text{kg P}}{10^6\ \text{kg}} \times \frac{27\ \text{kg Al}}{31\ \text{kg P}} \times 1.7 \text{ mole ratio} \times$$

$$\frac{594\ \text{kg Alum}}{54\ \text{kg Al}} \times \frac{\text{m}^3}{611.3\ \text{kg Alum}} = \frac{.4\ \text{m}^3}{\text{day}} = \frac{16.8\ \text{liters}}{\text{hr.}}$$

$$\text{or } \frac{200{,}000\ \text{gal.}}{\text{day}} \times \frac{8.34\ \text{lbs.}}{\text{gal.}} \times \frac{20\ \text{lbs. P}}{10^6\ \text{lbs.}} \times \frac{27\ \text{lbs. Al}}{31\ \text{lbs. P}} \times 1.7 \text{ mole ratio} \times$$

$$\frac{594\ \text{lbs. Alum}}{54\ \text{lbs. Al}} \times \frac{\text{gal. of Alum}}{5.1\ \text{lbs. Alum}} = \frac{106\ \text{gal. of Alum}}{\text{day}}$$

Based on an estimated cost of $0.21 per gallon, the expected cost of alum will be $22.60 per day or $8,250 per year.

Disinfection

Disinfection with chlorine is utilized throughout the country; however, recent awareness of potential formation of harmful chlorine compounds and residual toxicity in the stream, combined with the high ammonia levels of the Peet Packing effluent, led to the investigation of alternate methods of disinfection.

Chlorine dioxide was chosen because it does not combine with ammonia to produce chloramines, it is a stronger oxidant than chlorine(17), and it has the potential for disinfection at smaller dosages than chlorine solution. When chlorine is added to a wastewater, it rapidly combines with ammonia to form monochloramines, dichloramines and trichloramines, all of which are termed combined chlorine residuals. The monochloramines and dichloramines have reduced disinfecting power and are extremely slow reacting(18), and it may take up to two hours contact time to be useful as a disinfectant(19).

"Free chlorine" is a term used for hypochlorous acid (HOCl) which is a stronger, much faster acting disinfectant. Some estimates indicate disinfection capability of monochloramine is approximately one-one hundredth that of free chlorine(19). In order to obtain a "free chlorine residual" in wastewater containing ammonia, enough chlorine must be added to result in "breakpoint chlorination" which requires a minimum of 10 mg/l of chlorine for every 1 mg/l of ammonia(19)(20). In drinking water treatment, "breakpoint" chlorination is a common practice to ensure complete disinfection. In wastewater disinfection, it usually is not necessary to "breakpoint" chlorinate to achieve the disinfection levels required (based on fecal coliform); however, since chlorine dioxide is a disinfection agent equivalent to "free chlorine", it has the potential for achieving the required disinfection levels at a much smaller dosage.

The generation of chlorine dioxide requires the mixing of a chlorine solution and sodium chlorite ($NaClO_2$). The reaction is as follows:

$$2\ NaClO_2 + Cl_2 \rightarrow 2\ ClO_2 + 2\ NaCl$$

In theory therefore, 1.00 kg of chlorine dioxide requires 1.34 kg of pure sodium chlorite and 0.5 kg of chlorine(19). Since sodium chlorite is typically manufactured 80% pure, 1.68 kg of sodium chlorite is required and an overdose of chlorine is used to ensure a complete reaction, therefore a 1:1 ratio by weight of chlorine to sodium chlorite is recommended(19). The procedure is to pump a sodium chlorite solution with a metering pump through a glass clyinder filled with porcelain rings; the cylinder is also fed chlorine solution from a standard chlorinator. When the proper amount of chlorine is added to the sodium chlorite solution, the mixture turns greenish yellow providing visual indication of the formation of chlorine dioxide. Sodium chlorite is shipped dry and should be mixed with water to a convenient strength daily.

The typical chlorine dioxide dosage requirements for the Peet Packing Company were estimated assuming 2 mg/l chlorine dioxide would provide a sufficient fecal coliform kill. With a flow of 760 m^3/d (200,000 gpd), the estimated feed rates can be calculated as follows:

$$\frac{760\ \text{m}^3}{\text{day}} \times \frac{1{,}000\ \text{kg}}{\text{m}^3} \times \frac{2\ \text{kg ClO}_2}{10^6\ \text{kg}} = \frac{1.5\ \text{kg ClO}_2}{\text{day}}$$

$$\frac{1.5\ \text{kg ClO2}}{\text{day}} \times \frac{1.68\ \text{kg NaClO}_2\ \text{required}}{\text{kg ClO}_2} = \frac{2.5\ \text{kg NaClO}_2}{\text{day}}$$

for a 1:1 ratio also provide $\frac{2.5\ \text{kg Cl}_2}{\text{day}}$

$$\text{or } 200{,}000\ \text{gpd} \times \frac{8.34\ \text{lbs.}}{\text{gal.}} \times \frac{2\ \text{lbs. ClO}_2}{10^6\ \text{lbs.}} = \frac{3.3\ \text{lbs. ClO}_2}{\text{day}}$$

$$\frac{3.3\ \text{lbs. ClO}_2}{\text{day}} \times \frac{1.68\ \text{lbs. NaClO}_2\ \text{required}}{\text{lbs. ClO}_2} = \frac{5.5\ \text{lbs. NaClO}_2}{\text{day}}$$

and for a 1:1 ratio also provide $\frac{5.5\ Cl_2}{day}$

Based on an estimated cost of sodium chlorite and chlorine of $0.80 and $0.20 per pound, respectively, the expected cost of year-round disinfection would be $5.50 per day or $2,020 per year.

It is difficult to estimate the required dosage of straight chlorine to achieve disinfection at the Peet Packing Company; however, an estimated usage of 20 to 30 mg/l is not unreasonable considering the 50-60 mg/l of ammonia present in the effluent. The estimated chlorine usage at 20 to 30 mg/l would be 15-23 kg/day (33-50 lbs./day) and the expected cost of year-round disinfection would be $6.60 to $10.00 per day or $2,400 to $3,650 per year.

The actual cost savings for the use of chlorine dioxide on a high ammonia waste will only be shown through operational experience; however, the potential is significant and the additional capital cost to provide the capability to generate chlorine dioxide in addition to normal chlorination equipment is modest. At Peet Packing the additional diaphragm metering pump, 105 gallon tank, tank stand, solution diffuser, generator (glass cylinder), back pressure valve, pressure relief valve and anti-siphoning valve had a total cost of $2,300.

Additional related equipment includes a PVC chlorine dioxide (or chlorine) diffuser located in a flow channel prior to the flow measurement flume and following clarification, and two concrete contact chambers 3 m long x 1.2 m wide x 2.4 m deep (10 ft. long x 4 ft. wide x 8 ft. deep) each, of which will provide 35 minutes contact time at a flow of 760 m^3 (200,000 gpd). Redwood planks are used for baffling to provide an over and under flow pattern and to avoid short circuiting.

It should be noted that dry sodium chlorite requires special handling in that it is flammable when it is in contact with organic material such as gloves, sawdust, brooms, etc., and can ignite with heat or friction(19). No danger is involved in handling the material if care is exercised and precautions are followed, such as large amounts of flushing water should be used to wash down any spills. Sodium chlorite once mixed with water presents no further hazard.

It should also be noted that test samples tested once a month over a 2 year period indicate that the fecal coliform counts of the aerobic lagoon effluent remain below the 400/100 ml discharge requirement much of the year, and usually only go above that level when the aerobic ponds are frozen over. This indication also needs to be verified, however, as during warmer months algae interference with the membrane filter test used has been noted and may be creating erroneous results.

CONSTRUCTION SUMMARY

The construction of the wastewater treatment facility was advertised for competitive bids in two steps. Since the clarifier equipment, including weirs and baffles, required the longest delivery time, bids for this equipment were solicited prior to completion of plans and specifications for the remaining portions of the facility. Proposals were received from three manufacturers in January, 1977, and the equipment was awarded to the lowest bidder. Following completion of plans and specifications, an "invitation for bids" was advertised. Included in the contract documents was an assignment of the previously accepted clarifier equipment to the contractor's bid, this made the equipment supplier responsible to the contractor. The Peet Packing Company chose to do all of the electrical and instrumentation work with plant personnel. Construction bids were received in March, 1977, and the contract was awarded to the lowest bidder at $193,000. Construction began on May 1, 1977, and was substantially complete by October 31, 1977.

INITIAL OPERATING EXPERIENCE

Difficulty in getting the facility fully operational has been experienced due to hard winter weather; however, alum and polymer have been fed for phosphorus removal for the majority of the period between November, 1977, and the time of this writing, March, 1978. A limited amount of data has been analyzed during this period using "Standard Methods"(21). It appears, however, that 80% phosphorus removal can be achieved using the original estimated alum dosage of 1.7:1 mole ratio of Al:P. This dosage is equivalent to a 1.5:1 weight ratio of Al:P, or 25 liters alum per kg incoming phosphorus (3 gal. alum/lb. incoming P) assuming an alum solution of 1,332 kg/m^3 (11.1 lbs./gal.) $Al_2(SO_4)_3 \cdot 14H_2O$ with 60 kg/m^3 (0.5 lb./gal.) Al. The alum/phosphorus sludge characteristics observed have been very encouraging thus far, as the sludge both settles and thickens well. No disinfection data has yet been attained.

CONCLUSIONS

1. An evaluation of the disinfection of a lagoon effluent with high ammonia concentrations indicates that the use of chlorine dioxide is not only more environmentally sound but potentially less costly than disinfection with chlorine.

2. Phosphorus removal from lagoon effluent can be reliably achieved with chemical addition and clarification. Chemical requirements are similar to those experienced at secondary municipal treatment plants, and sludge characteristics appear to be excellent.

3. An evaluation of alternatives for ammonia removal indicated that land application utilizing border strip irrigation was more economical than mechanical treatment if an appropriate site can be found. Of a number of mechanical treatment alternatives evaluated, an oxidation ditch system appeared to be the most economical.

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PHYSIOCHEMICAL TREATMENT OF RENDERING WASTEWATER BY ELECTROCOAGULATION

by

Ernest R. Ramirez* and Odgen A. Clemens*

ABSTRACT

A large rendering plant processes between 500 and 700 tons of material per day. It handles feathers, fats, various forms of meat, etc. in a Carver-Greenfield rendering operation. This unit produces approximately 1000 M^3 per day of wastewater, while the air scrubber discharge, feather cooling water discharge, and cooling tower overflow account for 871 M^3/day, 757 M^3/day and 246 M^3/day, respectively. The 1000 M^3/day from the rendering operations is processed through a two-step electrocoagulation system before it is discharged to the city.

The wastewater treatment operation uses both sulfuric acid additions as well as alum for coagulation. The process is operated close to the zero zeta potential (zero surface charge) of the pollutant particulates. Extremely high reductions in suspended solids (97%) and fats and oils (98%) are achieved with the two-step electrocoagulation technology.

Skimmings are dewatered in the same basin in which they are formed by using dissolved air dewatering. Their solid content lie between 13.7 weight percent and 17.5 weight percent.

INTRODUCTION

A large rendering plant in North America processes approximately 600 tons of renderable material per day. The plant has only one objective; that involves rendering. Wastewaters from the plant are discharged to the municipality and subsequently to a river. The municipality has established guidelines for receiving plant discharge and has set the following figures as acceptable for effluent from a wastewater treatment system:

A. Suspended Solids - not to exceed 200 mg/l.

B. Hexane Extractables - not to exceed 100 mg/l.

C. BOD was not included in the restriction list.

The guidelines also specify that the limits established are for water leaving the pretreatment system. Dilution with other waters, such as cooling waters, etc., would not be considered as a measure of reducing pollutants in the water.

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* Swift Environmental Systems Company, Oak Brook, Illinois

The local environmental agency also specified that spills and other mishaps in the plant will not be permitted to influence the restrictions established. In this regard it became manditory to include a recycle system in the pretreatment unit should these mishaps occur. This safeguard is carried out by turbidimetric control.

Material rendered at the plant includes carcasses, bone fragments, hair, feathers, etc. Discharge waters leaving the plant must fall within the pH range of 5.5 to 9.5 units.

Odor problems encountered at the plant included that of ammonia mercaptans and hydrogen sulfide. Ultimately it was understood that these odors would, in due time, also be eliminated by proper treatment procedures. Management decided that it would be more intelligent to handle the problems piecemeal and start by first treating the wastewater to meet discharge permit guidelines. (This decision was, indeed, unfortunate.)

Plant Equipment and Wastewater Sources

The heart of the rendering plant consists of a Carver-Greenfield rendering unit. Wastewaters leaving the Carver-Greenfield overall operation pass through a natural flotation-sedimentation basin having dimensions of 9 feet wide by 40 feet long by 5 feet deep. This basin has both a top skimmer device as well as a bottom drag. Waters entering this sedimentation-flotation basin emanate from: (a) feather condensates, (b) feather pit, (c) truck wash, (d) Carver-Greenfield condensates, (e) raw material pit, (f) blood system, (g) Carver-Greenfield ejector condensates, and (h) miscellaneous floor washings, etc. A breakdown of the water volumes and their pollutant loading is given in Table 1.

TABLE 1. WASTEWATER SOURCES ENTERING NATURAL FLOTATION-SEDIMENTATION BASIN

	GPD approxi.	BOD5 Total mg/lt	SS mg/lt	FOG* mg/lt
Feather Condensates	10,000	6,540	2250	20
Feather Pit	21,000	4,430	5320	-
Truck Wash	16,000	2,270	527	126
Carter-Greenfield (C.G.) Condensates	70,000	4,210	1510	800
Raw Material Pit	21,000	10,200	4100	2100
Blood System	30,000	57,000	910	60
C.G. Ejector Condensates	100,000	700	-	-
Miscellaneous, Floor Wash, Etc.	20,000	2,500	4100	2210
Total	288,000			

* Fats, oils and grease.

Another three sources of wastewater present at the plant are given in Table 2. These wastewaters do not pass through the natural flotation-sedimentation basin and will be discharged directly to the city.

TABLE 2. OTHER DISCHRAGE SOURCES IN PLANT

	M^3/Day Volume	GPD Volume	BOD_5 Total mg/lt	SS mg/lt	FOG mg/lt
Air Scrubber	871	230,000	-	270	15
Feather Cooling Water	757	200,000	-	-	-
Cooling Tower Overflow	246	65,000	-	300	-

In summary, four principal wastewater sources emerge from the plant. These are: flotation-sedimentation basin, air scrubber discharge, feather cooling water discharge, and cooling tower overflow. Total water discharge from the plant is in the range of 2974 M^3/day (780,000 GPD). The rendering plant is primarily concerned with the wastewater in the natural flotation-sedimentation basin which represents approximately 1000 M^3/day. The analyses of these wastewaters are given in Table 1.

Optimum Treatment Determination of Rendering Wastewater

Wastewaters from the air scrubber discharge, feather cooling water discharge, and cooling tower overflow will not be treated by the LectroClear installation. These waters will simply be added to the discharge from the LectroClear operation.

In evaluating the wastewater, the following three steps were carried out using a batch-type two-step portable LectroClear unit together with a streaming current detector.

A. Determination of the pH of zero streaming potential (also zero zeta potential).

B. Determine the minimal treatment of alum or ferric sulfate to meet goals (one liter samples).

C. Determine the optimum cost effective dosage for treating the wastewater to comply with the established discharge guidelines of less than 200 mg/l of suspended solids and less than 100 mg/l of hexane extractables (one liter samples).

A series of analyses were carried out on the wastewater from the natural flotation-sedimentation basin on different dates. In each case a composite sample was taken. The results of these analyses are shown in Table 3.

TABLE 3. ANALYSES OF WASTEWATER LEAVING NATURAL FLOTATION-SEDIMENTATION BASIN

	BOD5			
	Total mg/lt	Soluble mg/lt	SS mg/lt	FOG mg/lt
Sample 1	7480	3400	4475	880
Sample 2	7800	3500	2720	740
Sample 3	4800	1470	3280	820

Determining pH for Zero Zeta Potential

A streaming current detector (manufactured by Waters Associates, Inc.*) was used to determine the surface charge on the pollutant particulates. This was done by taking small 50 cc aliquot samples and determining the streaming current value at various pH values. Sulfuric acid was used for pH adjustment. Results of this study are shown in Figure 1. These results clearly show that the surface charge on the pollutant particulates average approximately zero at a pH of 4.2. Also shown is that, as the pH is reduced and as it approaches 4.2, the charges on the pollutant particulates become less and less. The reduction in surface charge (negative) encourages the particulates to agglomerate and aggregate. On letting this wastewater stand (at pH 4.2) for 1/2 hour, it was found that most of the pollutants agglomerated and either floated or sank. The supernatant liquid had a Jackson Turbidity Value of 500 units. This fact confirms that at a zero streaming potential the tendencies for pollutants to agglomerate are indeed appreciable. The relationship between the amount of acid needed to adjust pH as a function of pH is shown in Figure 2.

Power requirements needed to satisfactorily treat the wastewater at a zero zeta potential when only sulfuric acid is used as the coagulant (and 6 ppm anionic polymer) are shown in Figure 3. The results of Figure 3 show that the wastewater can be reduced to a turbidity of 300 Jackson Turbidity Units by the application of 5 ampere minutes (at 12 volts) per liter of wastewater processed. A detailed analyses of the treated wastewater at 5 ampere minutes per liter are shown in Table 4. Because this operation is carried out at a zeta potential approximately equal to zero, it is being referred to as LectroClear-Z.

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* 16 Fountain Street, Farmingham, Mass.

LECTRO - CLEAR Z TREATMENT
STREAMING POTENTIAL VS. pH OF RENDERING WASTEWATER

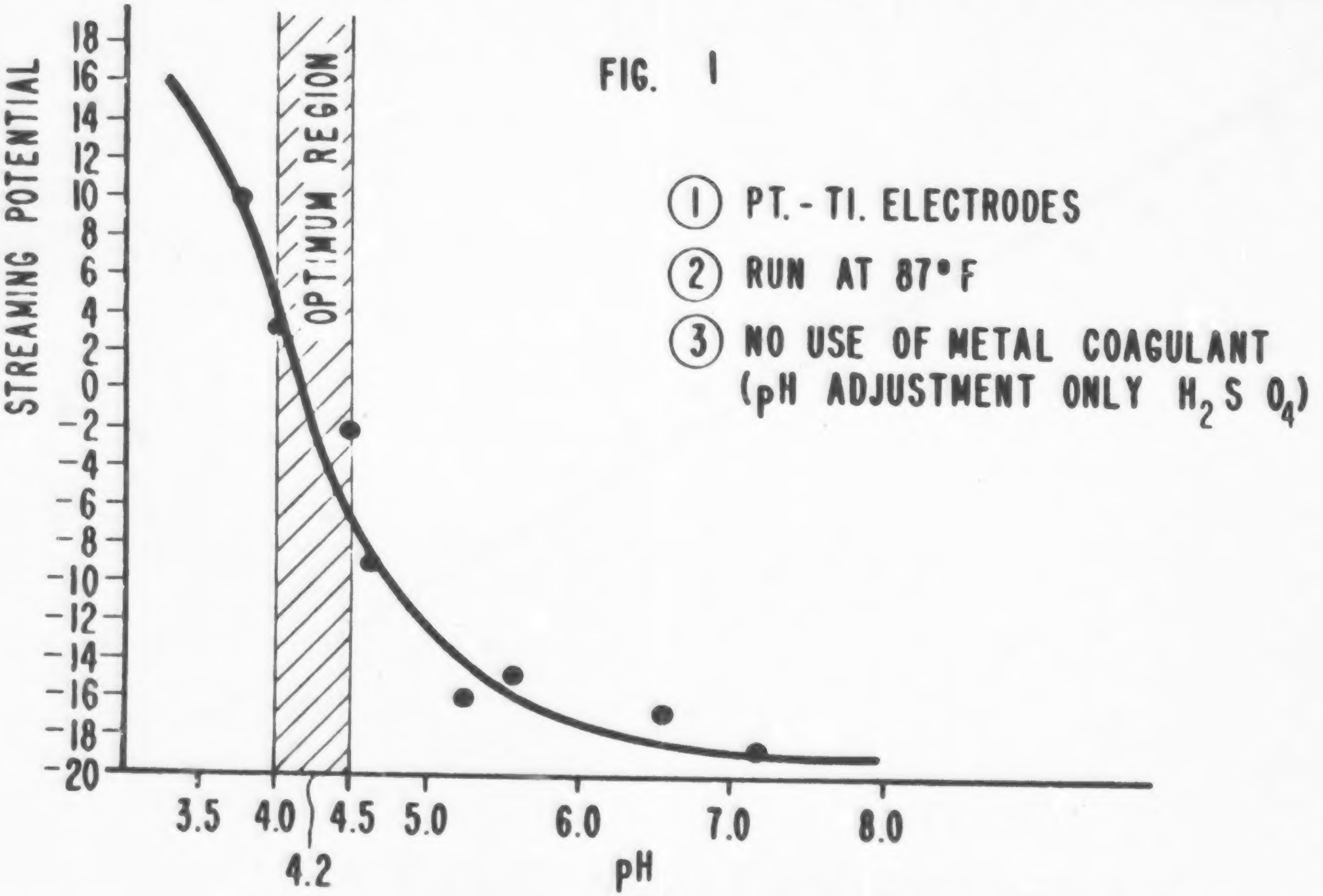


FIG. 1

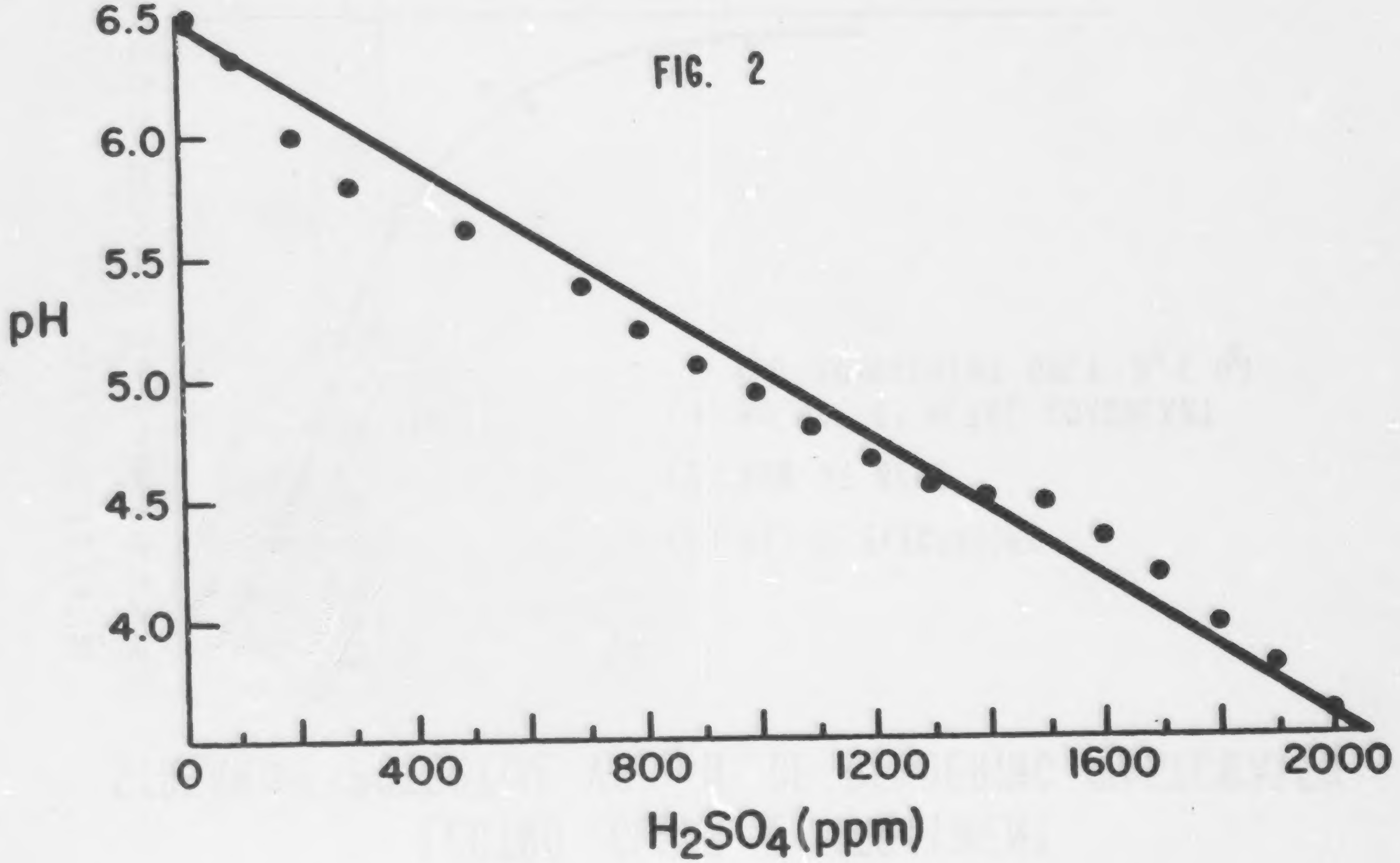
① PT. - TI. ELECTRODES

② RUN AT 87° F

③ NO USE OF METAL COAGULANT
(pH ADJUSTMENT ONLY H_2SO_4)

RENDERING WASTEWATER (7-5-77)

FIG. 2



Electrolytic Power Input As A Function Of Turbidity
At pH Of Zero Surface Charge (Acid)

FIG. 3

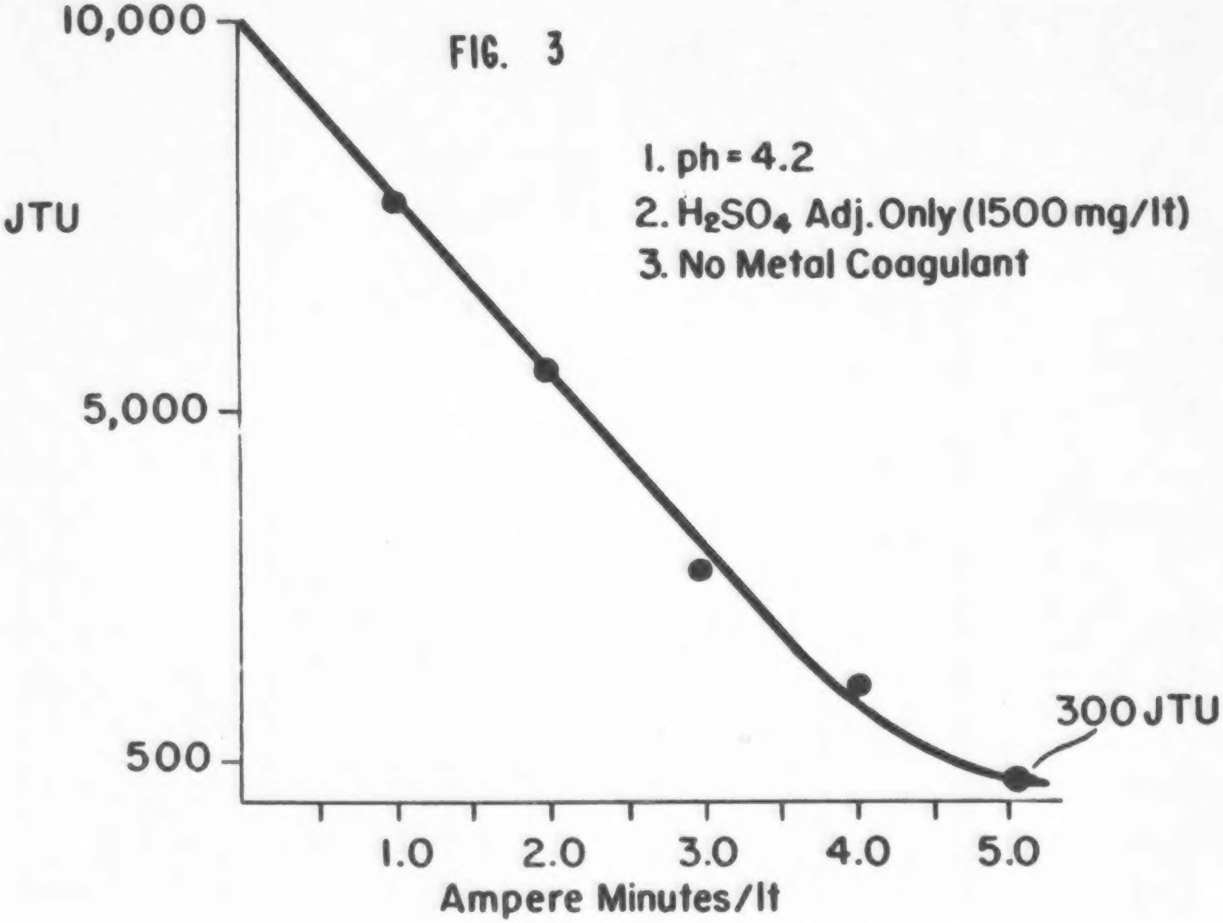


TABLE 4. TREATING RENDERING WASTEWATER WITH ELECTROCOAGULATION AT ZERO ZETA POTENTIAL

Sample Description	Treatment	SS (mg/lt) Influent	SS (mg/lt) Effluent	FOG (mg/lt) Influent	FOG (mg/lt) Effluent
Rendering Wastewater	(a) H_2SO_4 to pH 4.2 (b) 6 mg/lt of anionic polymer (c) 5 ampere min/l	3680	310	750	80

Treating Rendering Wastewater with Trivalent Metal Coagulants Only

It was found that the rendering wastewater could be satisfactorily treated to a zero surface charge when 500 ppm of ferric sulfate or 500 ppm of alum were used in the treatment. Under these conditions, the pH of the wastewater was reduced from its original value of 7.4 to a value of 6.2. With this treatment the wastewater could be satisfactorily treated with a power input of 2 ampere minutes (at 12 volts) per liter. Analysis of the wastewater so treated is given in Table 5. The turbidity of this wastewater was found to be 50 Jackson turbidity units. Since this process uses only a metal coagulant (and an anionic polymer of 6 mg/lt), it is referred to as LectroClear-M. (Figure 4).

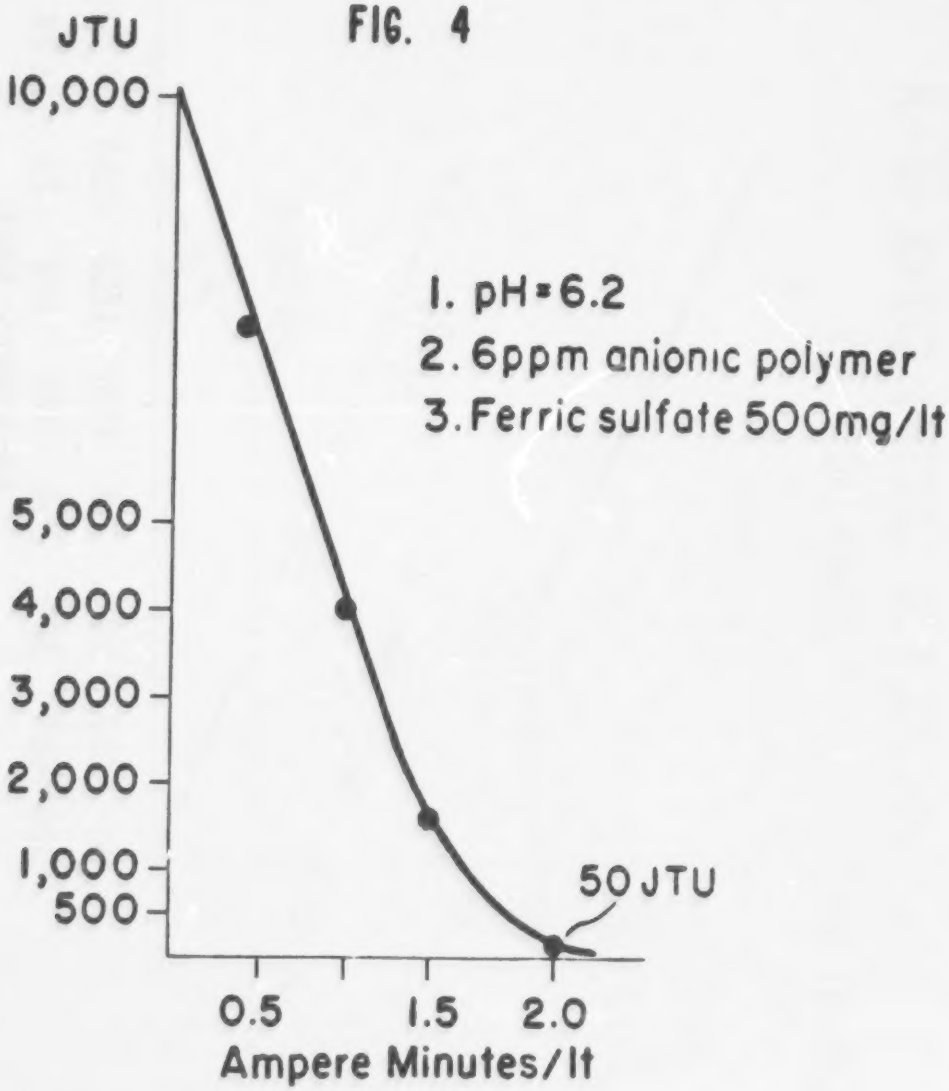
TABLE 5. TREATING RENDERING WASTEWATER WITH ELECTROCOAGULATION AND FERRIC SULFATE

Sample Description	Treatment	SS (mg/lt) Influent	SS (mg/lt) Effluent	FOG (mg/lt Influent	FOG (mg/lt Effluent
Rendering Wastewater	(a) 500 mg/lt Ferri Floc (b) 6 mg/lt anionic polymer (c) 2.0 ampere min/lt	3680	32	750	15

It will be noted that in this particular wastewater the LectroClear-Z process has higher chemicals costs than does the LectroClear-M operation (see Figure 5). Power input to obtain satisfactory results are also considerably higher in the case of the LectroClear-Z method. The most cost effective chemical treatment, however, is achieved by combining the use of sulfuric acid in addition to a trivalent metal coagulant. Consequently, the most cost effective operation taking into account chemicals is determined by using equation 1 for a series of satisfactory treatments.

Electrolytic Power Input Vs Turbidity At Zero Surface Charge (Trivalent Metal Coagulant)

FIG. 4



GRAPHICAL DETERMINATION OF MINIMUM COSTS FOR LECTRO CLEAR -Z-M
(EQUATION I)

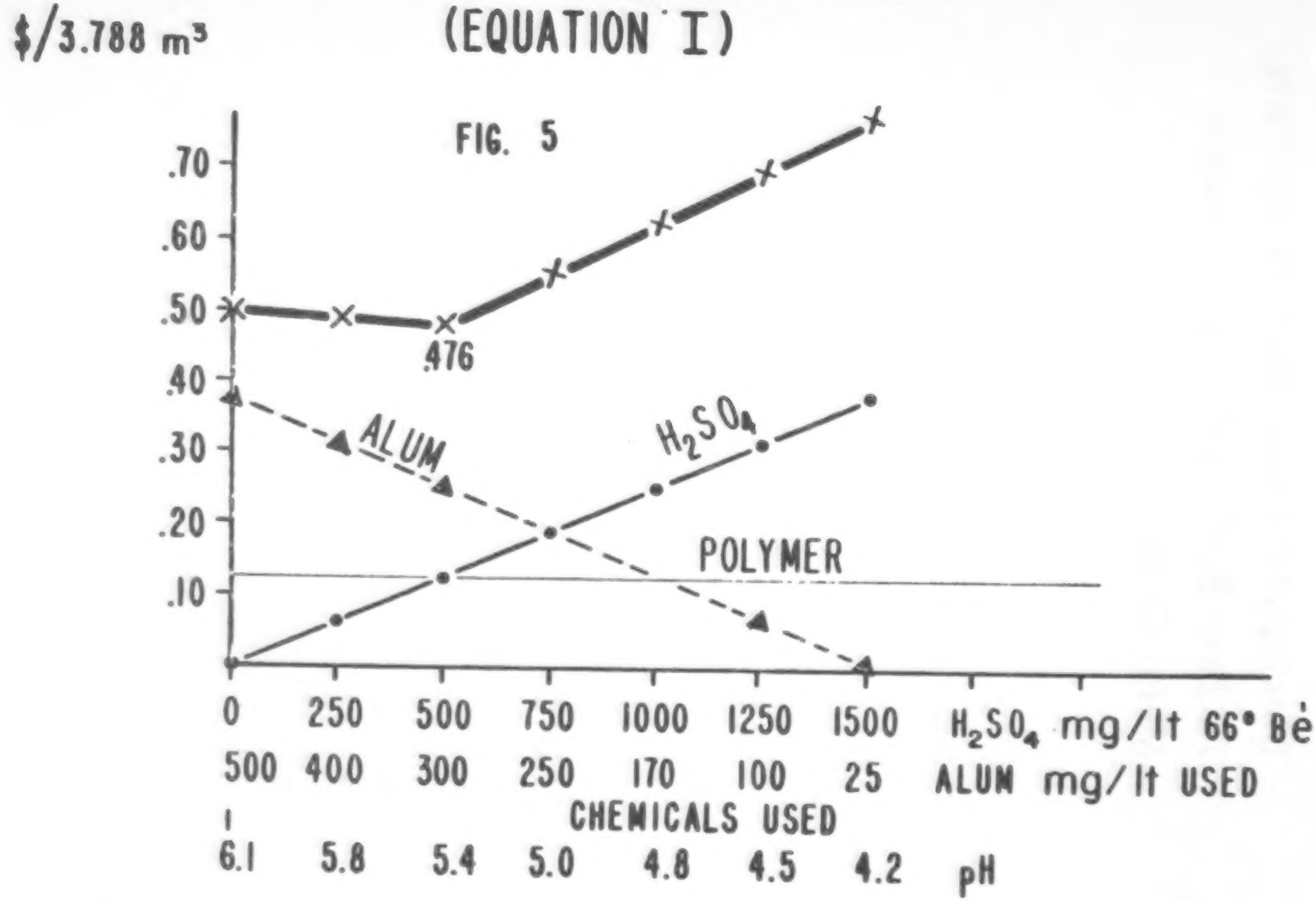


FIG. 5

Equation 1 - Chemical Costs

$\$/1000\ gal = \$/3.788M^3 = .00834\ [A \times B + C \times D + E \times F]$

where:

A = mg/lt trivalent coagulant used
B = \$/lb trivalent metal coagulant
C = mg/lt sulfuric acid used
D = \$/lb delivered H_2SO_4
E = mg/lt polymer used
F = \$/lb polymer used

for plant in question:

B = \$.09/lb
D = \$.03/lb
F = \$2.50/lb
E = constant 6 mg/lt

Most Cost Effective Treatment

By using equation 1 in conjunction with laboratory data, one arrives at the results given in Figure 5. In essence, all treatments given in the abscissa of Figure 5 treat the wastewater satisfactorily. The results show that the most cost effective treatment is 500 mg/lt H_2SO_4 (66° Bé), 300 mg/lt alum and 6 mg/lt of anionic polymer. Chemical cost of this treatment for the plant in question is \$.476 per 3.788 M^3 (1000 gallons).

The most cost effective treatment in plant A may not necessarily be so at plant B. Different cost of chemicals at different plants will necessarily lead to different cost effective treatments. It is, therefore, necessary that each plant determine its cost effective treatment based on chemical costs in existence at that plant. Hardness of the wastewater has an overwhelming effect on the most cost effective treatment. The wastewater at this plant was highly buffered with organic salts. This accounts for the exceptionally large amounts of acid needed. (See Figure 3.)

BASIC PRINCIPLE OF ELECTROCOAGULATION

The theory and principle of operation of the two-step electrocoagulation technology has been adequately described in prior literature (1, 2, 3, 4, 5, 6). A summary of the process, however, is given below. The technology involves two steps, the first having a duration of approximately 2 minutes. This step is called coagulation and the container in which it takes place is referred to as the coagulation cell or contact cell. A cardinal point of this first-step operation is that coagulants are added to the wastewater prior to the entrance into the coagulation cell. Likewise, pH adjustments are also made prior to the coagulation cell. Microbubbles in the diameter range of 50 to 100 microns are introduced into the coagulation cell at a concentration of 1 million to 100 million microbubbles per liter of wastewater. The 2-minute dwell time in the coagulation cell allows for intimate collisions between the pollutant particulates and the microbbubles. These collisions result in a pairing off of particulates with microbubbles. Upon leaving the coagulation cell, a polyelectrolyte is added and, at that point, a gross floc is formed in the flotation basin. This gross floc has entrapped in it better than 80% of the microbubbles generated in the coagulation cell. It is these microbubbles which provide buoyancy to the floc.

The flotation basin is the second step of the electrocoagulation technology. It involves a dwell time of approximately 25 minutes and electrolytic microbubbles are again used to float particulates to the surface of the water where they are subsequently skimmed off by a mechanical skimmer. A schematic of this two-step operation using electrolytic power is shown in Figure 6. While this paper deals with electrolytic power, both dispersed air and dissolved air microbubbles can also be effectively used in both the coagulation cell and the flotation basin. When electrolytic power is used, currents in the range of 1.3 ampere minutes/lt (5 ampere minutes per gallon) are used in the coagulation cell and approximately 1 ampere minute/lt (4 ampere minutes per gallon) in the flotation basin. Voltages employed are DC and in the range of 10 to 15 volts. The fact that the process actually treats the wastewater twice (once in each of the two steps) accounts for the improved treatment results over and above that attained in a dissolved air or electroflotation basin alone.

DESIGN CRITERIA AND CONSTRAINTS

The plant management has established that it would be important to have the skimmings with a minimum of water. The reason for this requirement is the plant has plans to render the skimmings for their protein and fat values. High water content would require higher rendering energy inputs and require a more costly operation. In view of this requirement, it was decided to dewater the skimmings in the basin itself. This is carried out with the use of dissolved air. The operation takes place in the electroflotation basin itself and is restricted to the first quartile of the basin, namely just as the skimmings are about to leave the basin.

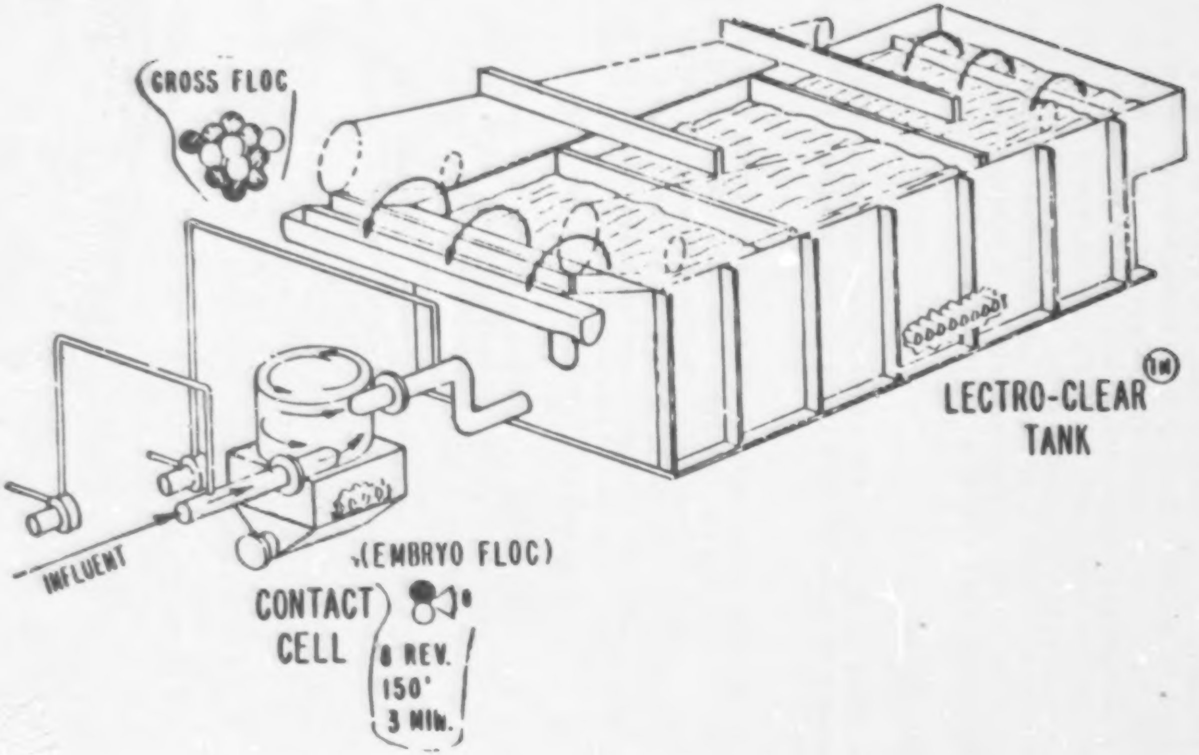
For dewatering to be effective there must be a skimmings blanket height of no less than 3 inches; a skimmings height of 4 inches or more is preferred. Under these conditions it would require that the skimmer arms be placed on a timer system whereby they would move 2 minutes out of every 4 minutes. (This ratio is not fixed but is a variable depending on the plant in question.)

The use of large amounts of metal coagulant (500 ppm) generally produces skimmings of higher water content and overall greater volume. Because of the constraints placed by the rendering operation, it was decided to use a LectroClear-Z-M operation where only a small amount of trivalent metal coagulant was added (less than 100 ppm).

Since management has decided that the skimmings would be rendered, it was decided to use the LectroClear-Z-M process where only a small amount of metal coagulant is added.

FIG. 6

SCHEMATIC – RENDERING



The plant management also felt that the use of the natural flotation-sedimentation basin will not be changed because substantial amounts of readily renderable fat were obtained from this operation. In this regard, the unit pays for its keep and, therefore, will not be altered.

In summary, it was decided that the final wastewater treatment design would consist of a LectroClear-Z-M unit which would incorporate a dewatering unit in the first quartile of the flotation basin. Both an electrocoagulation cell and an electroflotation basin would be used in the operation. Management further expressed the desire to obtain a stand-by dispersed air device as a source for microbubbles in the coagulation cell. This means that the electrocoagulation unit could be run either with electrolytic energy or mechanical energy (dispersed air). A failure in the rectifier would certainly make this decision worthwhile.

FINAL DESIGN

The final design for the LectroClear unit installed in this plant has a capacity of 1.14 M^3 (300 gallons) per minute. It consisted of the following:

A. One coagulation cell with a 2-minute retention time having an open top vortex chamber. The cell housed 90 Duriron TA-2 electrodes each 7 feet long. Surface-to-surface vertical spacing between electrode pairs is 3/8 inch. Horizontal spacing (surface to surface) between a set of electrode pairs is 2.5 inches. Rectifier for the electrocoagulation cell is 2000 amps with a maximum voltage setting of 20 volts. (See Figure 7.)

B. A dispersed air device precedes the coagulation cell and will be used on a stand-by basis. Motor used for the dispersed air device is 2 horsepower. (See Figure 8.)

C. The electroflotation basin is 8 feet wide, 38 feet long and 5 feet deep with 47 electrode pairs. (See Figure 9.)

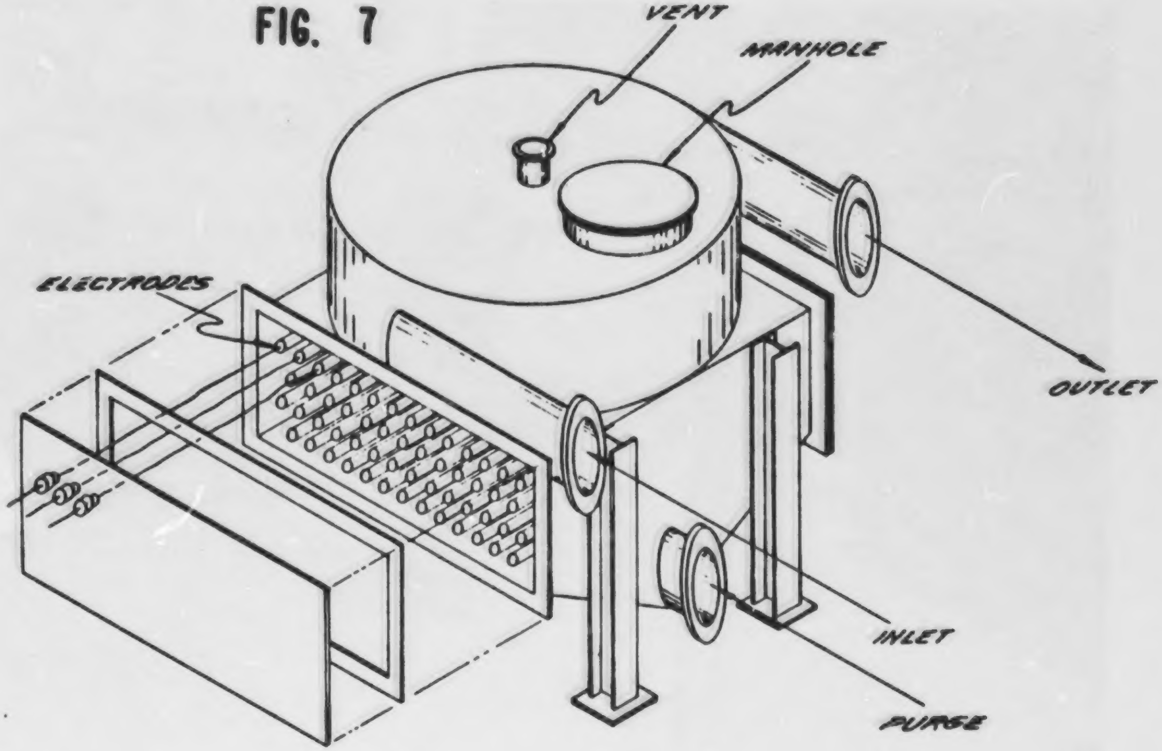
D. The skimmer device will not be perfectly level but will have an upward tilt of 6 inches per 100 lineal feet. This tilt will permit the basin to operate with a skimmings blanket of at least 3 inches on the influent side. (See Figure 11.)

E. The first quartile of the basin will use 30% recycled dissolved air for dewatering the skimmings. The dissolved air is introduced perpendicular to the wastewater flow with six 1-inch tubes, three on each side of the basin. The level at which the dissolved air is introduced is exactly at the mid-section of the basin. (See schematic 11.)

F. Four baffles with 50 percent free passage and with 2-1/2 inch circular holes was used. This condition minimized channeling in the electroflotation basin. A holding tank of approximately 100,000 gallons was used to equalize the flow. (See Figure 10.)

SCHEMATIC—ELECTROCOAGULATION CELL

FIG. 7



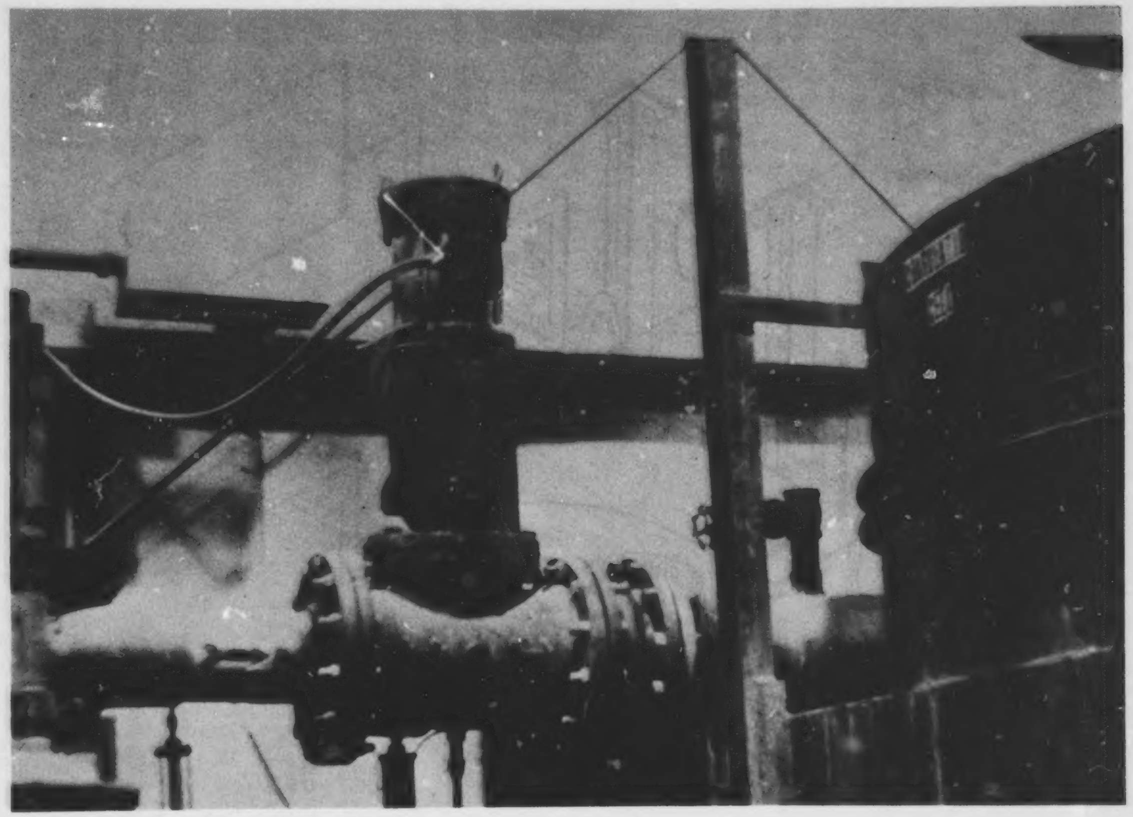


Figure 8. Dispersed air device.

Note the dispersed air device is placed just before the coagulation cell (to the right).

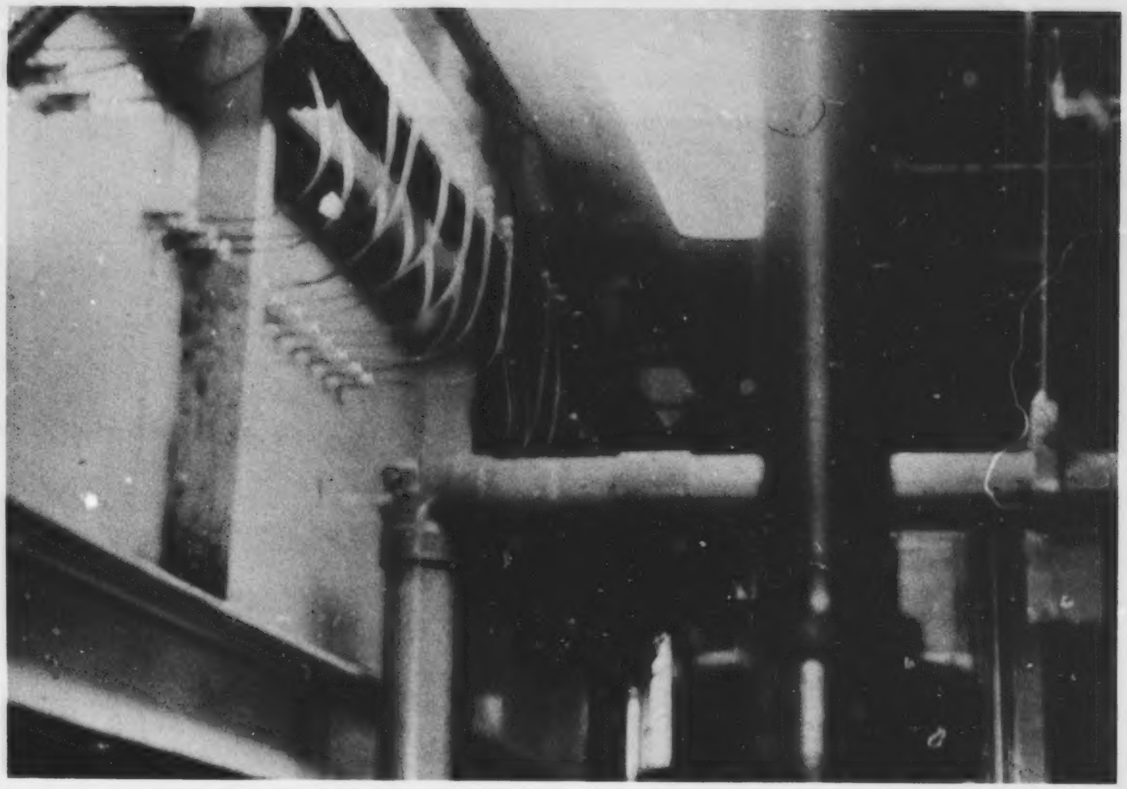


Figure 9. Electrode arrangement in basin.

Wiring is passed through a rubber pressure device.

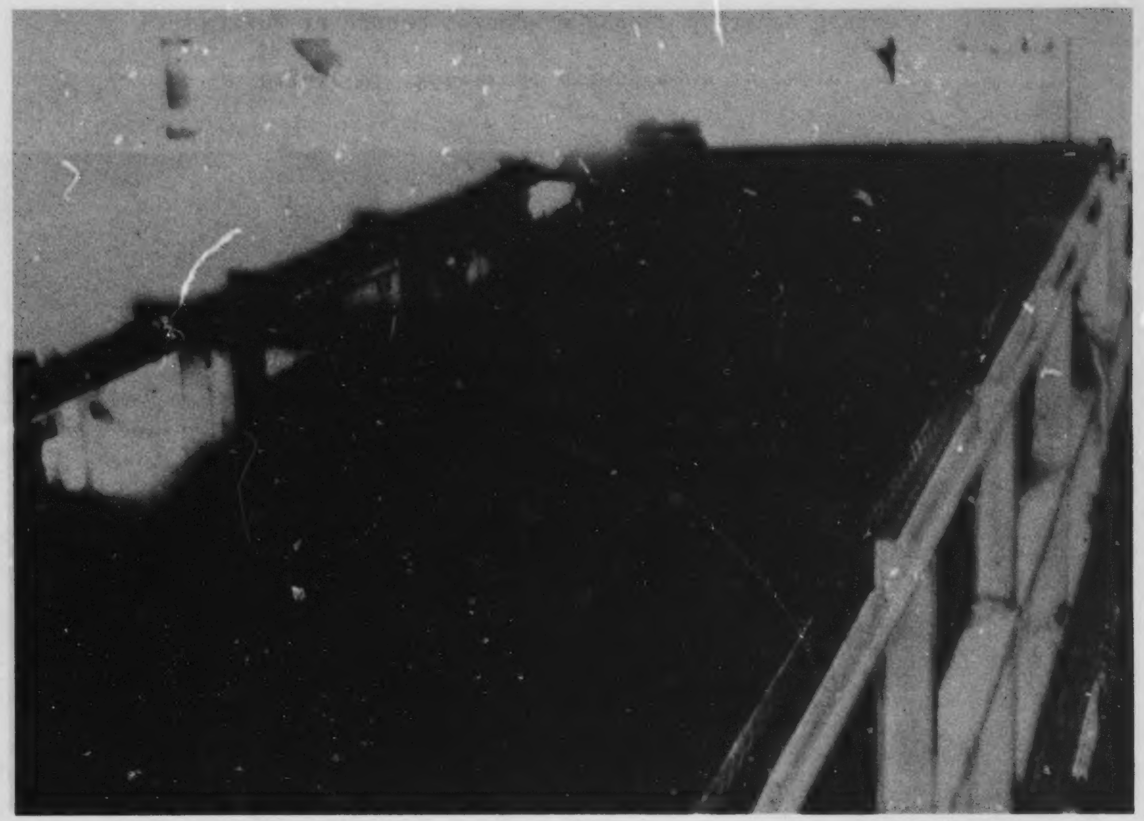


Figure 10. View of electroflotation basin and baffels.

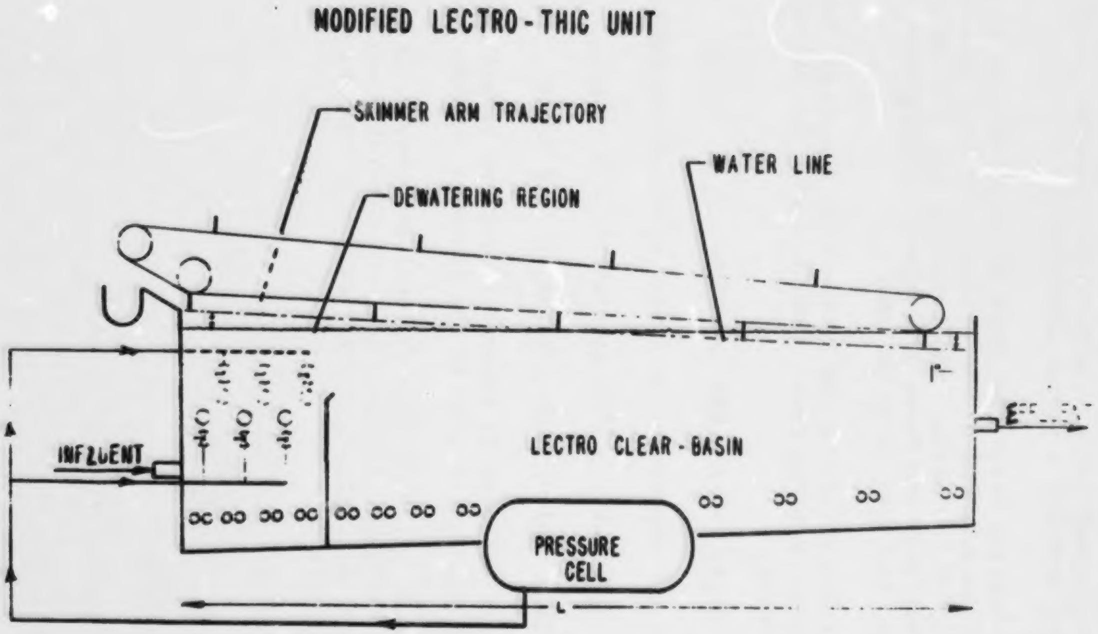


Figure 11. Schematic - electroflotation and dissolved air dewatering in same basin.

G. Automatic pH control was used. Dwell time in the pH adjustment tank is 4 minutes. This chamber is also equipped with a mechanical mixer. Both metal coagulant and sulfuric acid are added in this chamber.

H. At the insistance of management, turbidity control was installed. A Hach turbidity meter is used and, when turbidity is increased above a predetermined value, the treated wastewater is recycled to the holding tank for a second treatment.

I. The electroflotation basin contained 94 electrodes or 47 electrode pairs. Approximately 1/2 of these electrodes were placed in the first quartile of the basin. Their spacing was 3/8 inch apart (surface to surface) and these were placed on polypropolene saddles 12 inches from the basin bottom.

J. Finally, wastewater leaving the LectroClear treatment operation was pH monitored on a recorder. This provides the needed records for its discharge.

PERFORMANCE OF THE INSTALLED LECTROCLEAR-Z-M UNIT

Operating conditions of the wastewater treatment plant are as follows:

A. Electrocoagulation cell - 1500 amperes at 12.5 volts.

B. Electroflotation basin - 1400 amperes at 12.8 volts.

C. Dewatering unit employed 35 percent recycle at 55 psi gauge with a retention time of 4 minutes in the pressure chamber.

D. Wastewater flow - 1.14 M^3 (300 gallons) per minute, pH 4.5. Analysis of wastewater leaving the LectroClear-Z-M unit is given in Table 6. These analyses consist of 4-hour composites taken on two consecutive days.

E. Chemicals added are:

1. 1200 mg/lt sulfuric acid 66° Bé.
2. 100 mg/lt alum.
3. 6 mg/lt anionic polymer (X-400).
4. pH - 4.4 to 4.8.

Determination of solids content in the skimmings showed the following:

A. Lowest solids obtained - 13.7%.

B. Highest solids obtained - 17.5%.

Skimmings volume equaled between 4 and 7 volume percent of the wastewater treated.

TABLE 6. PERFORMANCE OF LECTROCLEAR-Z-M (pH 4.5) AT RENDERING PLANT

	Treatment			BOD	BOD			
	Alum mg/lt	H_2SO_4 mg/lt	Polymer mg/lt	Total mg/lt	Soluble mg/lt	SS mg/lt	FOG mg/lt	Protein* mg/lt
Run 1	100	1200	6					
Influent				7800	4800	4475	800	1080
Effluent				3850	3800	95	15	410
Run 2	100	1200	6					
Influent				6800	2100	3200	850	1100
Effluent				2200	2000	110	20	385
Run 3	100	1200	6					
Influent				8800	3500	2860	780	990
Effluent				3400	3200	80	22	340

* Nitrogen value x 6.25.

DISCUSSION

The described plant was designed to provide effluent wastewaters with less than 200 mg/l of suspended solids and less than 100 mg/l of hexane extractables. The fact that the plant in reality produced results much better than these is primarily attributed to the unique combination of a two-step primary treatment combined with a dissolved air skimmings dewatering unit.

Based on the unusually good results obtained by this design, it follows that the plant wastewater can be effectively treated by using only a trivalent metal coagulant or by using a combination of sulfuric acid and trivalent coagulant. The actual chemicals used will depend to some degree on the objectives of the plant.

In summary, a new dimension has been established in the wastewater treatment technology of rendering plants. This technology incorporates the following three factors in one operation.

A. Operates in the close vicinity of the zero zeta potential by the use of pH adjustment with sulfuric acid. This condition yields skimmings which are more easily renderable.

B. The operation employes a sequential two-step technology (coagulation cell plus flotation basin) where higher efficiencies are achieved in the removal of fats and oils and suspended solids.

C. The technique of dewatering skimmings with the use of dissolved air has the advantage of not requiring additional space, providing skimmings with a higher solids content and, lastly, removing additional amounts of the suspended solids in the wastewater as it passes through the dewatering section of the flotation basin.

CONCLUSIONS

The conclusions are based on wastewater from a particular rendering plant. Logic would say that they would apply to most rendering plants.

1. The average surface charge (streaming potential) on pollutants in the rendering wastewater evaluated approaches zero at pH of about 4.2. (See Figure 1.)

2. The combination of sulfuric acid, a trivalent metal coagulant, and a polymer provide for the most cost effective treatment. Due to the high buffer action of the rendering wastewater at the plant in question, unusually large amounts of sulfuric acid are needed. (See Figure 2.)

3. From a practical sense, the problem of treating the wastewater to meet predetermined effluent standards is just the beginning of the overall wastewater treatment problem. Such factors as cost effectiveness, odor caused by treatment, properties of the skimmings (renderability), and disposal of the skimmings are all integral parts of the wastewater treatment operation. The above are closely interwoven with corresponding plant costs. More often than not, simply providing treated wastewater with low suspended solids and fats and oil values will not adequately satisfy overall plant environmental conditions.

4. The use of a two-step primary treatment using a coagulation cell is especially effective in removing suspended solids and fatty materials from rendering wastewater.

5. The use of a dissolved air dewatering operation in the flotation basin itself is especially suitable and effective because it requires no added space for the dewatering operation. It also lowers the suspended solids in the effluent wastewater.

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PROTEIN RECOVERY FROM MEAT PACKING EFFLUENT

by

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INTRODUCTION

This report describes the Sterling Colorado Beef Company Alwatech protein recovery plant which is the first Alwatech recovery plant installed in the United States.

The Alwatech process is used for the reclamation of high energy, high quality protein concentrates from the fresh effluent wastewaters of fish, meat, and poultry processing plants. Recovery of saleable protein materials and simultaneous reduction by 60-90% of the pollution load (B.O.D.) of plant wastewaters are the dual objectives of this process.

The Alwatech process uses lignosulfonic acid (LSA) precipitation and dissolved air flotation for recovery of the protein concentrate for an animal food material. A 4% concentration of LSA as an energy source and/or pellet aid is authorized in mixed feeds, liquid feeds, and flaked grains in many countries (1) (2) (3). The Alwatech plant operation at Sterling Colorado Beef Company is currently being optimized.

BACKGROUND

Historical Development

The basic research work leading up to the Alwatech process was started in Oslo, Norway as early as 1960. At that time Leif Jantzen et. al. (3) developed a method for separating pure high molecular weight lignosulfonate (LSA) from sulphite liquor, and during studies of the properties of pure LSA, the ability of LSA to precipiate soluble proteins from dilute aqueous solutions was found to be a very promising application.

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° Data collection and evaluation of the Sterling Colorado Beef Company Alwatech plant is being conducted under an EPA demonstration grant.

Additional studies of the LSA precipitation of proteins resulted in a patented method. On the basis of this patented method, Alwatech was started in 1965 as a member of the Apothekernes Laboratorium for Special Preparater A/S (AL Group of Companies) of Norway.

Alwatech developed an industrial process using LSA precipitation of proteins for the treatment of wastewaters and recovery of proteins from abattoir, fish, and poultry plants.

Alwatech's early years of research and development were followed by the installation of plants in many countries and industries. Alwatech operates internationally, with subsidiaries and resident technical offices in a number of countries, including the United Kingdom and the United States.

Dissolved Air Flotation

Dissolved air flotation (DAF) has performed well for many years in the treatment of wastewaters. DAF is based on the fact that air is soluble in water in direct proportion to the pressure applied. When the pressure is released under the proper conditions, the air comes out of solution in the form of tiny bubbles. If a pressurized solution of contaminants, water, and air is agitated, and if the solution is released into an open vessel, the bubbles and solids will combine and float to the surface due to their reduced combined specific gravity. Then the float can be skimmed off of the surface.

Before DAF could be used productively by industries with high protein wastes, it was necessary to develop a means by which nutrients could be recovered from wastewaters at a low cost, biochemical oxygen demand (BOD) could be reduced, and dilute fats could be cheaply separated. Researchers have reported on a variety of chemicals that can be added immediately preceding the DAF process to achieve some or all of the above objectives. Barnett and Nelson (4) and D. B. Ertz _et_. _al_. (5) studied the effects of adding $Al_2(SO_4)$, and $Ca(OH)_2$, to the wastewater produced in the seafood processing industry. However, the above authors were solely concerned with meeting water quality standards and not with recovering an animal food product.

Wayne A. Bough _et_. _al_. (6), on the other hand, reported on a chemical which potentially could satisfy all the objectives. In their paper, the authors demonstrated the efficacy of chitosan, (an organic polymer composed of glucosamine residues) in producing a nutritious animal feed from wastewater. Although chitosan would appear to satisfy the needs of a number of industries with protein rich wastewaters, FDA approval is pending.

Thus, at the present time, the only chemical additive that can economically recover nutrients from effluent is lignosulfonic acid. This use of LSA was developed by Alwatech A/S, of Norway, and is marketed under the trade name of Alprecin in Europe. Because the Sterling Colorado Beef Company is the first company in the United State to incorporate the Alwatech process, the following discussion is particularly relevant for U.S. firms.

GENERAL DESCRIPTION OF THE ALWATECH PROCESS USING ALPRECIN

The Alwatech process is a unique patented system for the recovery of a dry saleable meal from abattoir, poultry packing, and fish processing wastewaters. The process also treats these wastewaters to the point where they can be discharged into municipal sewers.

The Alwatech process is based upon the specific precipitation of proteins (7) by purified high molecular weight lignosulphonates (ALPRECIN), under acid conditions. Lignosulphonates are chosen because, unlike alternative chemicals, they can precipitate dissolved blood, and they are accepted as animal feed additives by both the European Economic Community and the Federal Drug Administration.

The high molecular weight lignosulphonate is derived from sulphite lye, a by-product of wood pulping, from which the major part of the carbohydrates, in themselves a source of pollution, has been removed.

The process wastewater from abattoirs, poultry packing plants, and fish processing industries exhibits a varying flowrate and will contain large amounts of suspended solids in addition to dissolved and emulsified fat and proteins. It is recommended that screening and a balancing tank be used to reduce surges in flow and quality.

To obtain the maximum benefit of the protein recovery and effluent treatment ability of the Alwatech process, it is sometimes advantageous to let some particular streams from a slaughterhouse undergo separate pre-treatment or by-pass the Alwatech plant altogether. Examples of the first kind is tripe wastewater and of the latter cattle pen wastewaters. Minimum balancing capacity is normally equal to 1/2 to 1 hour flow, depending on the production rate at the site. If a larger balancing capacity is installed, however, the plant operating hours may be extended up to 24 hours per day.

After screening, the equalized flow of wastewater is precipitated with purified high molecular weight lignosulfonic acid at a pH of approximately 3, the pH being reduced with sulphuric acid. Before the treated effluent is discharged into the sewer, or a subsequent biological treatment system, it is neutralized to a pH between 6 and 8 with calcium hydroxide or another base such as sodium hydroxide.

Following precipitation, the floc, which contains protein, fat, and suspended matter, is separated by dissolved air flotation.

From a typical wastewater with a BOD of 1,000 to 2,500 mg/l before any treatment, the Alwatech process normally produces an effluent of the following quality:

BOD	70 - 80% reduction
Suspended Solids	less than 300 mg/l
Fat	less than 75 mg/l

The concentration of the sludge as removed from the flotation system is normally 6 - 12% solids depending largely on the origin and pre-treatment of the process wastewater.

The sludge removed from the flotation tanks is neutralized with calcium hydroxide. At the same time, surplus or diluted blood may be added.

After neutralization, with or without blood, the sludge is processed through a coagulator to a filter belt for dewatering. A decanter (centrifuge) may also be used for dewatering.

The sludge will contain 30-50% solids after dewatering depending on the dewatering system used.

The water removed from the sludge in the dewatering process may contain up to 40% of the original lignosulphonate added in the chemical treatment process. In large installations, a lignosulphonate recirculation system is installed to reduce chemical consumption.

The concentrated (30-50% solids) sludge may be dried in a rendering plant, mixed with other by-products, or dried in a separate drier.

THEORY OF PRECIPITATION WITH LIGNOSULPHONIC ACID (LSA)

The theory of LSA precipitation was reported by T. R. Foltz, et. al's (7), and is quoted below:

> "The precipitation of soluble protein with soluble lignosulphonic acid in an acidic aqueous system is believed to be a nearly instantaneous reaction involving the negatively charged sulphonate groups on LSA molecules and positively charged amine groups present on the protein molecules. The complexing of these large molecules results in a gelatinous suspended material that can be removed by a suitable physical liquids-solids separation technique.
>
> "Protein molecules contain both positively charged amine groups and negatively charged carboxyl groups when the solution is at pH values near 7. Acidification of proteinaceous waste water to pH values below the isoelectric point will result in proteins carrying a net positive charge. Isoelectric values vary with different proteins, but acidification to 3.5 or below normally insures a pH below the isoelectric for most protein solutions.
>
> "Lignosulphonic acid when in solution has the sulphate group essentially completely ionized, resulting in a net negative charge on the LSA molecule. With acidification, the strong acid group of the sulphonate continues to carry a negative charge even at pH values of 2 to 3. At extremely low pH values below 1, the sulphonate group begins losing its charge."
>
> "Table I summarizes the respective net charges on LSA and protein molecules at various pH ranges, noting the resulting precipitation potential.

Table 1 INFLUENCE OF pH ON LSA - PROTEIN PRECIPITATION.

pH Range	Protein	LSA	Precipitation
0 - 1	Positive Charge	Weak Negative Charge	Poor
2 - 3	Positive Charge	Negative Charge	Good
3.5 - 4.5	Isoelectric (no net charge)	Negative Charge	Poor
Above 4.5	Negative Charge	Negative Charge	None

"This table reveals that the pH must be in range of 2-3 to obtain effective precipitation. Actual experimental evidence confirms that this is the optimal pH range for precipitation of the maximum amount of protein.

"Because the precipitation involves balancing of opposite ionic charges, it follows that an optimal ratio exists between LSA and proteins in order to maximize protein removal with the least amount of LSA. Experimental evidence also confirms that treament of proteinaceous wastes with LSA is quantitative, making LSA dose control important.

"In precipitating and removing the LSA and protein complex, fat and fatty material (as determined by hexane soluble extraction) are also largely removed. In raw waste, fat is primarily particulate and emulsified matter with a free fatty acid content ranging from 5 to 50 per cent of the total fat content. Acidification of raw wastes eliminates the strong negative charge on the free acid carboxyl groups resulting in a loss of water solubility. Therefore, at protein precipitating pH values, most of the fat material tends to separate from the water and float to the surface. The presence of LSA would not be expected to enhance fat removal if protein matter was absent from the raw wastes.

"With protein present and forming an insoluble material with LSA, the fat tends to be comingled with the protein LSA material."

THE USE OF ALWATECH RECOVERED PROTEIN CONCENTRATE AS ANIMAL FEED

The Alwatech Protein Concentrates

The composition of these protein concentrates is dependent primarily on the sources of the raw material and the components of the effluent treated. From fish and meat sources which have been the most investigated and utilized to date, high quality components are assured because the material is dominantly muscle, blood, and fat.

Flesh particles, dissolved blood, and released fat are treated within approximately 1-2 hours at pH 3 so that the freshness and bacteriological condition of the raw material is excellent and superior to many other by-product animal foodstuffs

The LSA concentration in the dry matter of the protein concentrates may vary from 5 - 15% but is normally about 10%. The following tables show typical analyses of Alwatech protein concentrates recovered from wastewaters in the fish and meat industry.

An illustrative average analysis of the Alwatech herring protein concentrate is comparable with commercial herring meal with due allowance for the LSA content (Table 2).

Table 2 COMPARISON OF RECOVERED PROTEIN WITH HERRING MEAL.

	Commercial herring meal,%	Alwatech herring protein concentrate, %
Crude protein (organic nitrogen x 6.25)	69	71
Fat	8	9
Calcium	4.8	4.7
Phosphorus	2.8	2.8
Sodium	1.4	1.6
LSA	0	10

Table 3 ANALYSIS OF A SAMPLE OF MATERIAL RECOVERED BY THE ALWATECH PROCESS AT KBS, SWEDEN (PRIMARILY PORK SLAUGHTERING).

		%
Protein	-	56.0
Oil	-	15.0
Fiber	-	2.5
Nitrogen Free Extracts	-	20.0
Ash	-	6.4

The amino-acid composition of the protein in Alwatech protein concentrate meals has been determined for products obtained from fish and blood processing (1). It may be seen from Table 4, that the composition is unaffected by the LSA treatment. This would be the expected result from conventional acid precipitation of proteins extensively studied including fish, egg, soya, groundnut, and casein whose amino-acid composition is altered only by virtue of loss of certain components in the mother liquor, (i.e. non-precipitated fraction) and not by precipitation as such.

Table 4 AMINO-ACID COMPOSITION OF PERCENTAGE CRUDE PROTEIN.

	Fish		Blood	
	Untreated %	LSA Precipitated %	Untreated %	LSA Precipitated %
Cystine	1.0	1.1	0.9	0.9
Aspartic acid	9.0	9.0	9.4	8.7
Methionine	3.2	3.4	2.9	2.9
Threonine	4.6	4.7	4.6	4.4
Serine	4.1	4.0	4.5	4.2
Glutamatic acid	14.1	14.5	13.6	13.2
Glycine	5.6	5.5	7.4	7.3
Alanine	6.3	6.2	6.7	6.5
Valine	5.6	5.1	5.0	4.9
Isoleucine	4.7	4.4	4.7	4.3
Leucine	6.9	6.6	7.3	7.3
Tyrocine	2.1	2.2	2.9	2.3
Phenylanine	3.6	3.8	4.0	3.9
Lysine	7.3	7.2	8.2	7.8
Histidine	2.2	2.2	2.4	2.2
Arginine	5.0	5.3	6.0	6.0

The digestible protein determined by the pepsin-hydrochloric acid method showed that the feed value of proteins precipitated with lignosulphonates is only 15-20% lower than for equivalent unprecipitated blood meal. This must be considered as an unexpected good result because it is known from the works of B. Naess (8) that lignosulphonates have an inhibiting effect on pepsin under acid conditions.

In the trypsin system, however, there is no such inhibiting effect, and to determine the complete feed value it is necessary to include the Trypsin method. Moreover, it was found that protein precipitated by ordinary sulphite lye had a lower feed value than protein precipitated by Alprecin.

PROTEIN QUALITY AND FEEDING TRIALS

LSA is a purified derivative from wood pulping liquors which has been fed extensively to many animal species for many years in dried form. Extensive tests under controlled conditions reported in 1973 (9) show that relatively high levels of sulphite liquor concentrates in animal feed does not affect feed conversion.

The harmless nature of LSA in rat and poultry feeds has been borne out in feeding tests of protozoa, rats, and chickens to determine the protein quality and feeding value of Alwatech protein concentrates. Up to 4% of crude LSA as an energy source and/or pellet binder is authorized in mixed (compound) feeds, liquid feeds, and flaked grains in many countries with a wide range of feeding practices and ration formulations (2). The products contain 60% lignosulphonate, which implies a safe level in feed stuffs of 2.5% LSA or less. This is above the anticipated inclusion rate in feeds from Alwatech protein concentrates of which a relatively small tonnage would be available, compared with the quantity of other protein and energy ingredients in farm animal diets.

Provided normal and conventional practices in the drying of protein products from industrial processes are followed, protein quality should be equivalent to that of the starting material. Indeed blood proteins, fish solubles or by-product fats, for example, probably receive longer and possibly more severe drying conditions than Alwatech protein concentrates.

In the abattoirs and meat packing industry, the recovered material can be added to renderable material for production of meat-bone meal and technical fat, or dried separately. A number of feeding trials with Alwatech recovered protein concentrates show that the feeding values of the recovered material are comparable with existing market qualities and that substitution of up to 50% in fish meal or soya bean meal feed mixture with Alwatech protein concentrate (APC) does not affect live-weight gain, feed conversion ratio, or mortality.

Poultry feeding trials have been carried out as chicken growth tests (10), poultry screening tests and pelleted feed tests.

Table 5 shows a typical result obtained by three groups of 510 chicks on a diet containing 22% crude protein where the APC content is substituted for herring and soyabean meal.

Table 5 RESULTS OF CHICK FEEDING TRIALS.

	Herring 4%	APC 4%	APC 8%
Mortality			
0 - 7 days	35	22	34
8 - 49 days	13	6	8
Live-weight gain			
50 days (g)	1270	1290	1311
Feed conversion ratio	2.13	2.10	2.05

Pig feeding trials have been conducted with addition of LSA in amounts of 3% and 12% of the feed (11) with the Alwatech protein concentrates substituted for parts of or all of the soyabean meal in the diet. These pig feeding trials show that the LSA content in feed can be up to 6% and that 50% of the soyabean meal can be replaced by Alwatech protein concentrate without any significant effect on live-weight gain, feed conversion, or mortality.

DESCRIPTION OF THE ALWATECH PROCESS INSTALLED AT STERLING COLORADO BEEF COMPANY (SCB)

Plant Capacity

This effluent protein recovery system has been designed to treat up to 3,000 cubic meters per day (800,000 gpd) of wastewater containing 4,100 kilograms (9,000 pounds) of BOD5 and 5,400 kilograms (12,000 pounds) of suspended solids over 16 hours. At this BOD_5 loading, the nominal capacity of the effluent treatment plant is 200 cubic meters per hour (52,000 gph).

Table 6 shows the current loading at the balancing tank of the Sterling Colorado Beef Company packing plant. The test data presented are based on 4-hour composite samples.

Table 6. CURRENT WASTEWATER CHARACTERISTICS AT SCB.

	Minimum	Average	Maximum
BOD_5, mg/l	1,500	2,274	4,900
COD, mg/l	2,200	3,572	6,320
Suspended Solids, mg/l	740	1,825	2,650
Oil and Grease, mg/l	320	1,140	4,040
Flow, gpd		513,500*	
Beef processed, head/day		1,750	
Average live weight, pounds		1,031	

* This flow rate is the average treated through the Alwatech plant during preliminary testing and does not reflect the total water used at Sterling Colorado Beef Company.

The plant has been designed to remove 70% of the applied BOD load, reduce the suspended solids to less than 300 mg/l, and reduce oil and grease to less than 75 mg/l.

It is estimated that the plant will recover approximately 4,500 kilograms (10,000 pounds) of dry solids per day from dewatered sludge containing 60 - 70% moisture. The dewatered sludge has less than 10% fat on a dry weight basis. Tests have demonstrated that it can be dried in the existing rendering plant. It is possible that a separate drier could be used for the recovered product. The plant layout is shown in Figure 1, and Photo 1 shows the building that contains the Alwatech plant.

FIGURE I — STERLING COLORADO BEEF COMPANY ALWATECH PLANT LAYOUT

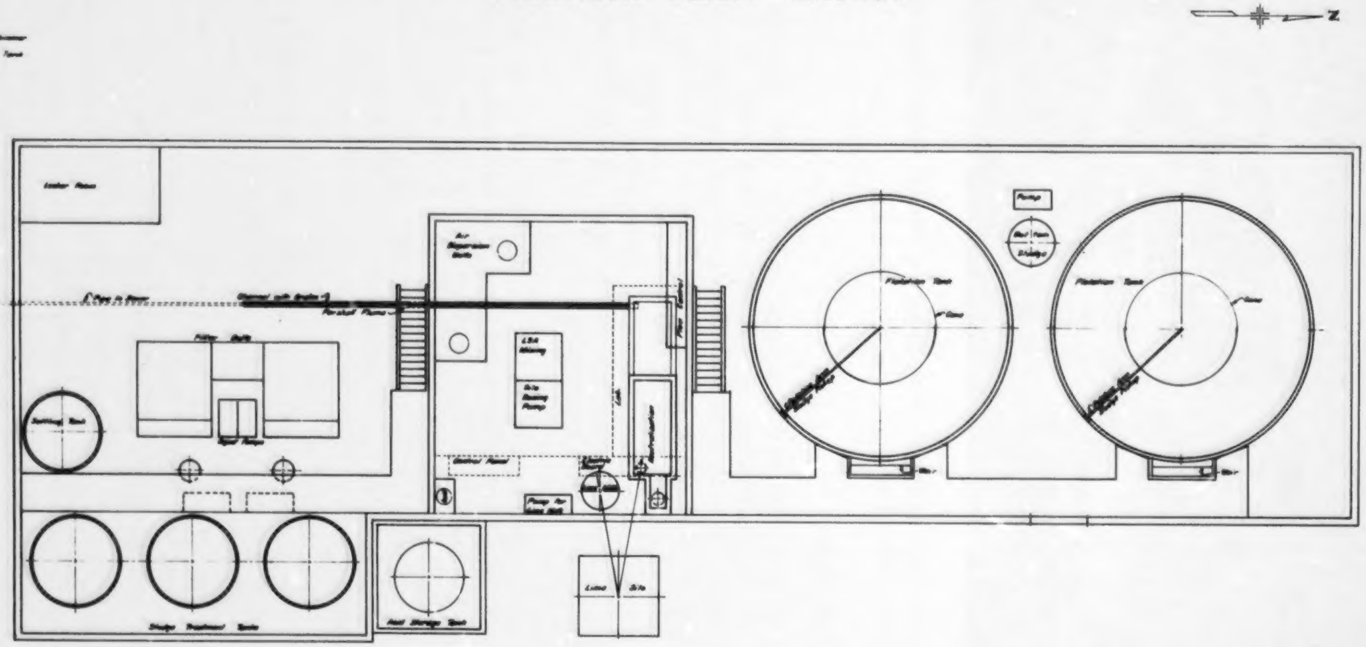

Photo #1 - Alwatech building at Sterling Colorado Beef Company, Sterling, Colorado.

Wastewater Pre-Treatment

SCB has approximately 1,500 cubic meters per day (400,000 gpd) of process wastewater from the slaughtering operations with a BOD5 of 1,600 to 1,800 mg/l after screening. The wastewater is screened through a rotating screen at the rate of 120 cubic meters per hour (30,000 gph) before being discharged to a 300 cubic meter (80,000 gallon) circular clarifier equipped with a bottom scraper. The clarifier has provisions for removal of floating fat (grease). Solids removed by the screen and from the surface of the clarifier are returned to rendering.

The clarifier, which was present prior to installation of the Alwatech plant, is now used as a combined clarifier and balancing tank. During the day the level in the clarifier is kept 15 to 30 cm below the overflow weir for grease removal while it is pumped 2.5 m (8 feet) down each evening. The night wastewater from the slaughterhouse is allowed to fill up the clarifier again overnight. Solids settled out in the clarifier are removed at regular intervals for recovery or deposited off site.

Approximately 65 cubic meters per day (17,000 gpd) of highly polluted effluent with a pH between 11 and 12 is discharged from the tripe washing department. This effluent is screened on a rotating screen before being discharged to the clarifier. Alternatively, the screened wastewater may be pumped to the Alwatech plant bypassing the clarifier. Solids removed by the screening operation are returned for rendering.

Blood coagulation is done in-line with live steam. Coagulated blood is separated on a shaker screen. The effluent originating from the dewatering of blood has a very high BOD and contains valuable suspended solids. This effluent is pumped to a settling tank and thereafter pumped directly to the Alwatech plant bypassing the clarifier. Settled solids are pumped to the Alwatech sludge dewatering system.

Sterling Colorado Beef Company has direct contact condensers in the rendering plant which discharge approximately 750 cubic meters per day (200,000 gpd) of condenser water at a temperature of 80°C (175°F). This particular wastewater contains very little fat or proteins for recovery in the Alwatech effluent treatment system. It has a BOD generally below the BOD level discharged from the Alwatech plant. Tentative plans are to discharge this effluent to the sewer.

Cattle pen wash water is screened on a shaker screen and discharged to two settling tanks in series. At present this wastewater bypasses the Alwatech system. SCB has approximately 70 cubic meters per day (18,000 gpd) of cattle pen wash water and after screening and settling it contains approximately 2,400 mg/l BOD.

All effluents from preparation of hides are discharged separately and are not treated in the Alwatech plant.

It is desirable to bypass the clarifier (balancing tank) with particular waste streams such as those from tripe operations and cattle pens, to reduce biological action in this tank. Biological activity in this tank has been found to reduce the protein content of the final product.

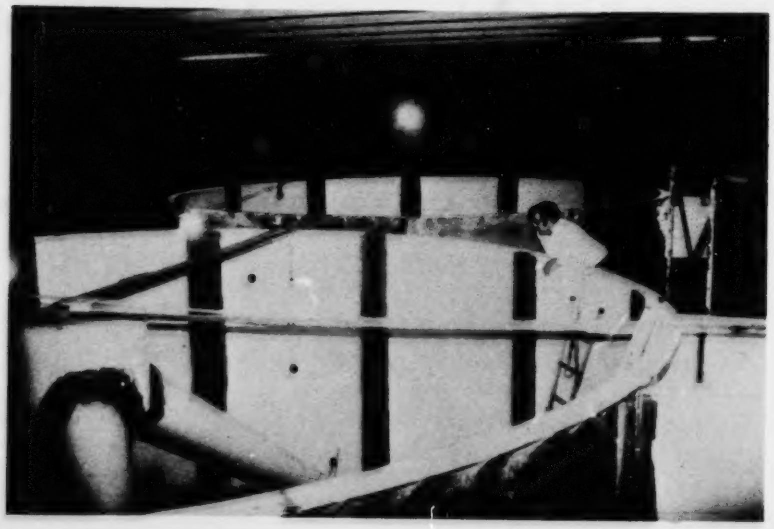

Photo #2 - DAF tanks being installed at SCB.

Alwatech Process Flow Description

Figure 2 is the Alwatech process flow diagram of the Sterling Colorado Beef Plant. The incoming wastewater is pumped by feed pumps M3 and M4 from the clarifier to flotation tanks I and II (See Photo 2). Before this wastewater enters the flotation tanks, LSA, H_2SO_4, and water (partly saturated with air) are added. LSA, which is delivered as a powder, is dissolved in water to a concentration of 10 to 15%. A dosing pump M6, adjustable from the control panel, delivers the needed quantity of LSA solution. H_2SO_4 is taken directly from a storage tank and diluted with wastewater before being added to the 2 flotation tanks. The H_2SO_4 is pumped by dosing pump M5 which is automatically controlled by the pH I equipment which utilizes electrodes that are cleaned ultrasonically.

Water, partly saturated with air, is produced from a mixture of water and wastewater by means of high pressure pumps M1 and M2, injectors, and pressure vessels I and II (See Photo 3). The treated effluent is neutralized with $Ca(OH)_2$ and is dosed by the neutralization dosing screw M19 (in the Lime Silo) which is controlled by pH II equipment (See Photo 4).

The protein sludge is removed from the surface of the 2 flotation tanks and pumped by flotation pumps M10 and M13 to the 3 sludge treatment tanks. Bottom sludge is removed from Flotation Tanks I and II by bottom scrapers M16 and M17, respectively, and pumped to the 3 sludge treatment tanks by bottom sludge pump M18. Sludge pumps M29 and M30 pump the protein sludge to heat coagulators I (M31) and II (M32), respectively (See Photo 5). Dewatering on Filterbelts I (M33) and II (M34) produces a combination protein fat concentrate containing approximately 40% dry matter (See Photo 6). Reject pumps M35 and M36 pump the liquid from the 2 filter belts to the flotation tanks influent line. The Alwatech process is controlled from a central panel containing the automatic equipment (See Photo 7).

Sludge on the bottom of the clarifier is pumped to the settling tank by sludge pump M37. Sludge pump M38 moves this concentrated sludge to the 3 sludge treatment tanks.

FIGURE 2 — STERLING COLORADO BEEF COMPANY
ALWATECH PROCESS CONTROL BOARD

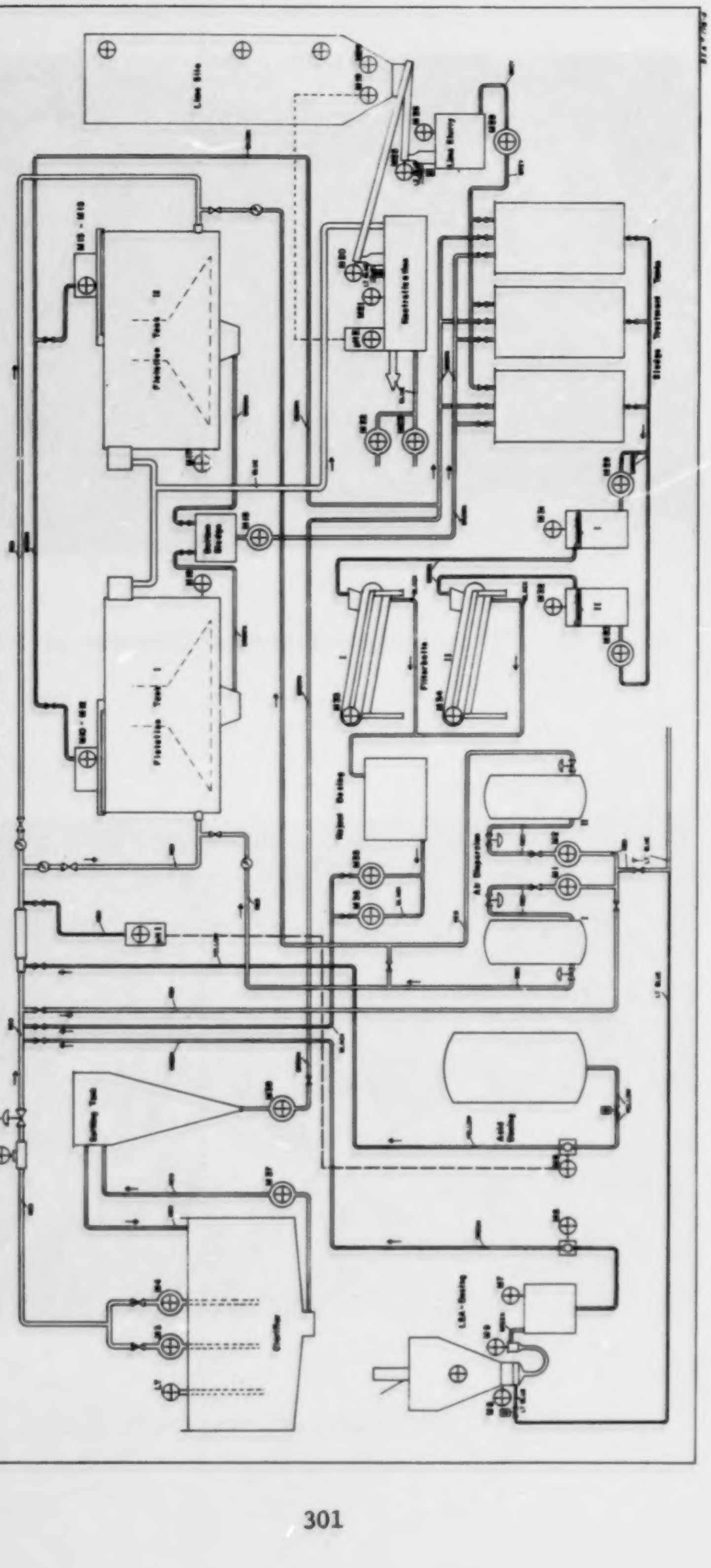

Photo #3 - Air Injection Pressure Chambers at SCB.

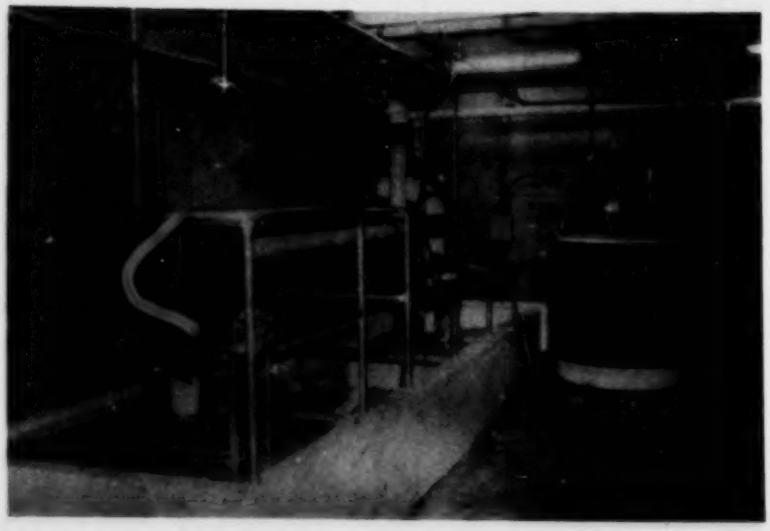

Photo #4 - Lime Neutralization Tank at SCB.

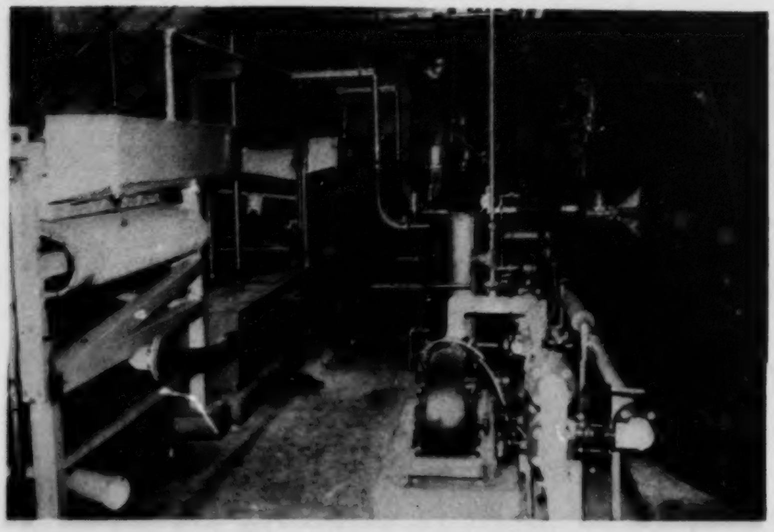

Photo #5 - Coagulators and Filter Belts for Sludge Drying at SCB.

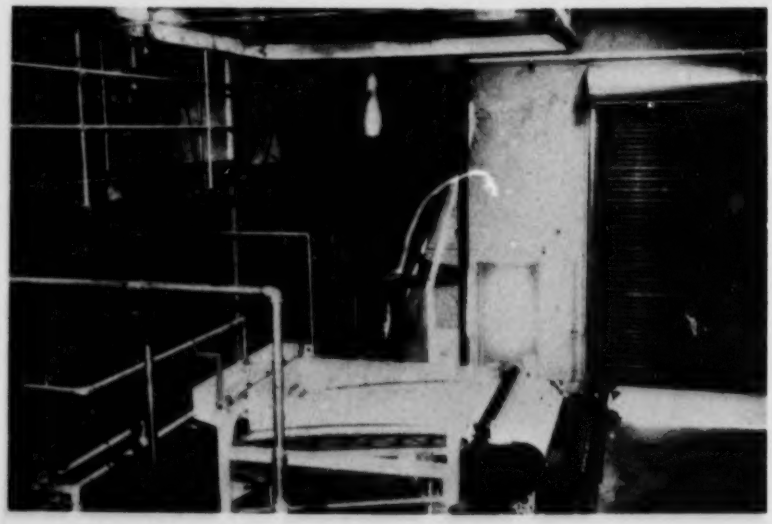

Photo #6 - Sludge Tanks and Filter Belts at SCB.

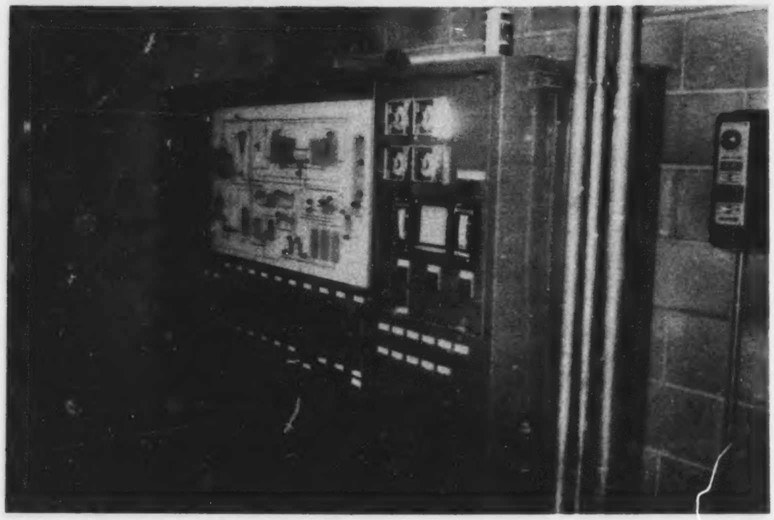

Photo #7 - Electrical Control Center for the Alwatech Process.

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A METHOD OF PHYSICO-CHEMICAL TREATMENT OF ORGANIC WASTEWATERS

by

P. Stephenson*

ABSTRACT

A process to treat organic wastewaters containing significant concentrations of protein and grease is described. Special reference is directed toward the treatment of meat packing plant effluent as it is for this application the majority of process data is available. Development is traced from initial effluent characterisation and experimentation, through pilot plant trials to preliminary full scale evaluation. Particular importance is attributed to the recovery of useful by-products and their application as a feed supplement for non-ruminant animals. In one instance treatment of a meat packing plant effluent, as discharged after primary treatment in a saveall or catch basin, resulted in 75-80% removal of chemical oxygen demand. Broiler grower chicken feeding trials using the by-product recovered from this treatment showed comparable growth to similar inclusions (0-14%) of conventional Meat and Bone meal supplements.

INTRODUCTION

The high organic content of many industrial wastewaters, especially those of the food processing industries, results in a considerable biochemical oxygen loading to effluent treatment plants and natural waterways. In the meat industry protein and grease bearing effluents, even after primary treatment to remove the bulk of floatable and settleable solids, are typically an order of magnitude stronger (based on BOD_5) than domestic wastewater.

For a typical New Zealand meat packing plant with an average wastewater flow of 6750 m^3/d (1.76 mgd (U.S.)) and, mean total organics concentration, after the removal of bulk solids in a saveall or catch basin, of 1800 mg/l the daily organic solids discharge would amount to approx. 12,150 kg/d. The significance of a suitable method of treatment and the potential for by-product recovery is therefore apparent.

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The Application of Physico-Chemical Processes

An intelligent approach to the selection of any treatment process initially involves characterisation of the wastewater over a significant time period and an assessment of the degree of treatment required for that particular plant location. Previous applications have involved partial treatment of sewage effluent by lime precipitation and acid cracking of wool scour effluent.

In general physico-chemical treatment systems are considered expensive in comparison with many biological treatment processes such as anaerobic lagoons. However when physico-chemical treatment permits the recovery of a valuable by-product and or water for reuse the project economics may be more favourable. This is especially so in urban localities where water and sewage charges are applicable and available land for the treatment plant is limited. Additional advantages include the adaptability of some systems to input effluent composition fluctuations and toxic environments, both of which significantly affect biological process performance.

Background to the Process Development

Initial studies in 1968-69 at the N.Z. Department of Scientific and Industrial Research on the application of regenerated cellulose based ion exchange resins for the removal of proteins and charged organic groups from meat packing plant effluents indicated that a pretreatment to remove high levels of grease and suspended solids was necessary to prevent resin fouling. It was also considered desirable to reduce the protein concentration to levels more attune to practical separation by ion exchange (max. 300-400 mg/l protein).

The pretreatment performance required was beyond that achievable by any form of mechanical screening, and biological processes affected a complete change in effluent composition. Thus a number of chemical treatment processes were investigated to remove the majority of effluent organics and produce an effluent more amenable to ion exchange.

Extensive trials, both laboratory and pilot scale, since 1968 have progressed to the stage where a reliable and efficient chemical treatment has been developed for large scale application. It is this process which is discussed in this paper. Throughout its development emphasis has been placed on a process which incorporates:

1. Reliability to input effluent composition and solids loading fluctuations.
2. A sludge with good dewatering characteristics.
3. A maximum possible reduction in biological oxygen demand (BOD_5).
4. The production of valuable by-products and water for reuse.

The chosen process in reality represents a compromise of these features. Its application to effluents from other food processing industries such as fish and poultry has been successful and current investigations involve the examination of its use in the treatment of a widespread range of organic bearing industrial effluents, especially those with high concentrations of protein and grease where by-product recovery is most likely.

PROCESS DESCRIPTION

In essence a chemical coagulation process is employed to remove a major fraction of the organics and suspended material remaining after primary treatment. The process involves a double pH shift with the addition of chemicals, resulting in the formation of a flocculated mass which is readily recovered and contains the majority of organics from the effluent.

The treatment process is sequentially summarised as follows:

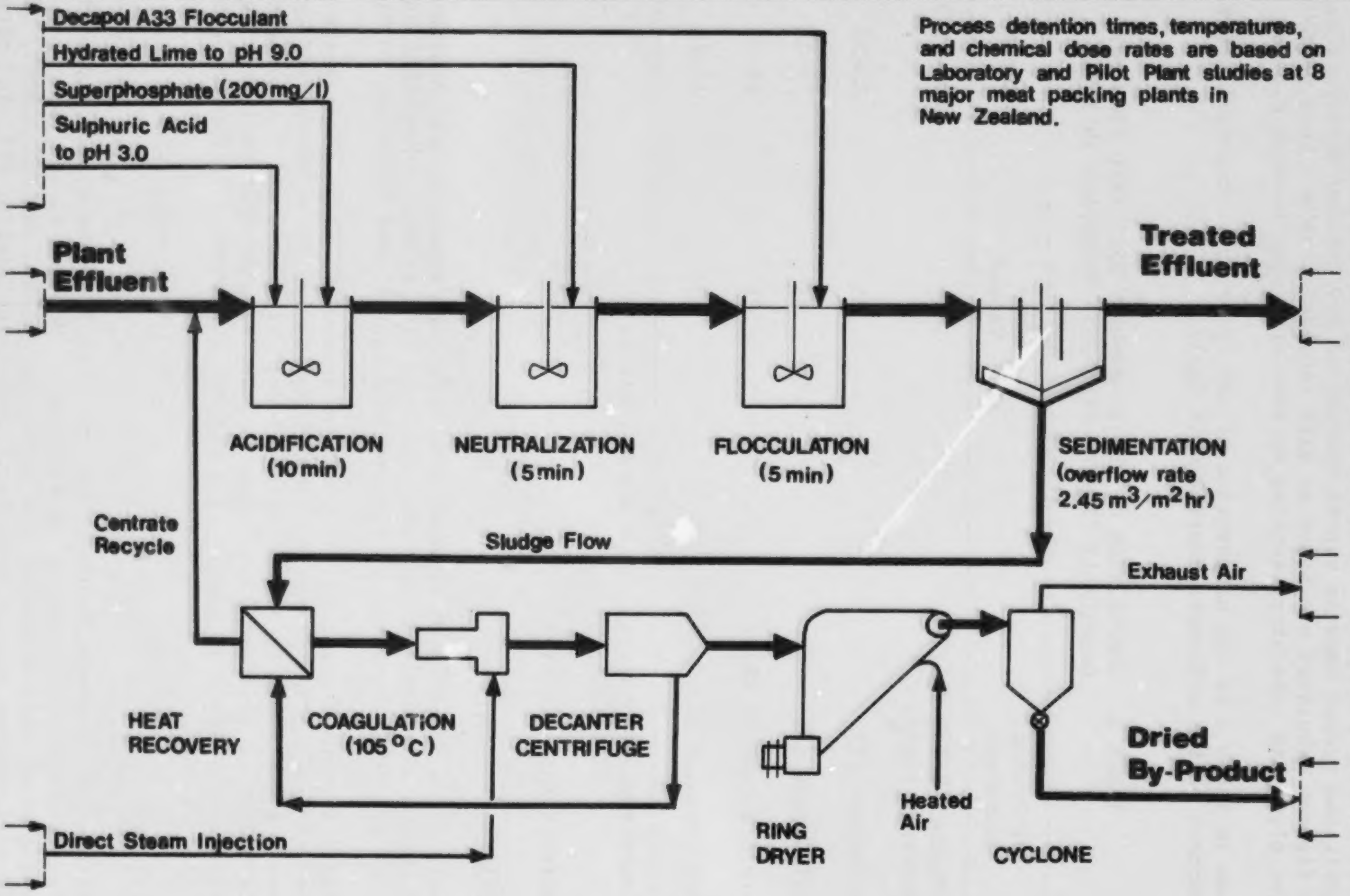
1. Sulphuric acid addition to denature protein. The reaction proceeds in a stirred tank maintained at a controlled pH corresponding to the isoelectric point of the solution.
2. Coagulant addition to the acidified effluent. The particular material selected will depend upon the process performance required and the proposed end use of the byproduct. In the treatment of meat packing plant wastes a phosphate coagulant is added in the form of crushed superphosphate.
3. Neutralisation. Stagewise addition of a lime slurry raises the pH and promotes further coagulation. The final stage is controlled at the optimum pH for flocculation.
4. A dilute flocculant solution is then added to the coagulated effluent and is dispersed under controlled hydraulic conditions.
5. The effluent is gently agitated in the flocculation chamber of a flocculator-clarifier to promote the growth of large, readily settleable flocs. Separation of these in the clarifier section then produces an effluent substantially free of suspended solids.
6. The settled solids are thickened, heated, centrifuged and pneumatically dried. Centrate is recycled to the untreated wastewater inflow stream.

The optimal chemical dose rates and retention times at the various stages of treatment are a function of the waste composition, treatment requirements, and engineering advantages. For a particular application these parameters are determined on the basis of laboratory and pilot plant studies. By way of example the most utilised scheme, and that employed to treat meat packing plant wastes, is detailed in Figure 1.

TREATED EFFLUENT QUALITY

Process performance is a function of the untreated effluent characteristics. Providing an effluent contains significant concentrations of grease and protein a reduction in Chemical Oxygen Demand (COD) of 75-80% may be expected for the coagulation process alone. In general an increase in solids loading and influent strength has resulted in improved removal efficiencies and greater by-product recovery, thus reducing fluctuations in treated effluent quality. Almost complete removal of grease and suspended solids has been achieved for the treatment of many effluents and Kjeldahl nitrogen reductions in excess of 50% are typical.

SCHEMATIC PROCESS FLOW DIAGRAM FOR CHEMICAL TREATMENT OF MEAT PACKING PLANT EFFLUENT (as discharged from a Saveall)



Process detention times, temperatures, and chemical dose rates are based on Laboratory and Pilot Plant studies at 8 major meat packing plants in New Zealand.

Figure 1

In Table 1 the process performance is summarised for the treatment of protein and grease bearing wastes typical of New Zealand Meat Packing Plants. The figures tabulated are based on data recorded over a 4 year period of pilot plant and laboratory testing on site at 5 meat packing plants.

Shown in Table 2 is the composition of the by-product recovered after treatment of the effluents described in Table 1.

TABLE 2. COMPOSITION OF THE BY-PRODUCT RECOVERED FROM THE CHEMICALLY TREATED EFFLUENTS DESCRIBED IN TABLE 1

By-Product Component	Mean Value*	Range
By-Product Total Solids Recovery (mg/l)	1685	1200-2270
Ash Content (%)	25	23-30
Total Grease (%)	27	15-35
Protein as Nx6.25 (%)	31	25-39
Other Organics (%)	17	12-23

*Composition as evaluated on a dry wt. basis.

CHEMICALS AND UTILITIES

Chemical Treatment

Fluctuations in effluent composition, buffering capacity, and solids loading are common and result in variable acid and lime demand. Coagulant and flocculant dose rates may be constant and apportioned according to flow.

Typical treatment costs (April 1976) on a chemical usage alone basis are shown in Table 3 for a meat packing plant wastewater as discharged from a saveall system used to remove bulk solids. Figures 2 and 3 illustrate the variability of acid and lime demand for the treatment of meat packing plant effluent from the five plants with wastewater characteristics as described in Table 1.

Utilities

Treatment plant power requirements vary with flow and composition, as these effect the specific capacity of equipment. However in the case of a meat packing plant with a nominal effluent flow, from a saveall system, of 4500 m^3/d charges (April 1976) for labour, electricity, oil, and steam will amount to approx. 5.8¢ (N.Z.)/m^3 (22.0¢/1000 U.S. gal.). The basis for this cost is shown in Table 4.

TABLE 1. PROCESS PERFORMANCE FOR THE CHEMICAL TREATMENT OF PROTEIN AND GREASE BEARING EFFLUENTS AFTER PRIMARY TREATMENT AT MEAT PACKING PLANTS IN NEW ZEALAND*

Effluent** Component	Untreated Effluent		Treated Effluent		% Reduction	
	Mean	Range	Mean	Range	Mean	Range
Chemical Oxygen Demand (mg/1)	2765	1570-3855	535	265-750	81	76-83
Total Solids (mg/1)	2525	1960-4120	1855	1305-3380	27	18-35
Suspended Solids (mg/1)	1235	890-1960	60	35-115	95	91-97
Total Organics (mg/1)	1705	1460-2010	700	455-910	60	45-71
Ash Content (mg/1)	820	250-2105	1155	420-2470	+41	+17-+105
Total Grease (mg/1)	550	400-690	20	15-30	96	94-99
Protein as NX6.25 (mg/1)	795	490-1170	370	225-560	53	49-59
pH	7.5	7.1-8.8	9.0	9.0		

* The Table records data from extensive laboratory and pilot plant studies at five different meat packing plants.

** All analyses as outlined in Standard Methods (2).

TABLE 3. TYPICAL CHEMICAL COSTS* FOR THE TREATMENT OF A MEAT PACKING PLANT WASTEWATER AS DISCHARGED FROM A SAVEALL SYSTEM

Chemical	Mean Concentration (g/m^3)	Unit Cost ($/tonne)	Treatment Cost ($/m^3)
Sulphuric Acid (98%)	275	73.	0.020
Hydrated Lime	385	50.	0.019
Phosphate Coagulant	200	30.	0.006
Flocculant	2	3250.	0.007
		Total Chemical Cost ($/m^3)	0.052
		($/1000 U.S. gals)	0.20

*Chemical cost in New Zealand as at April 1976.

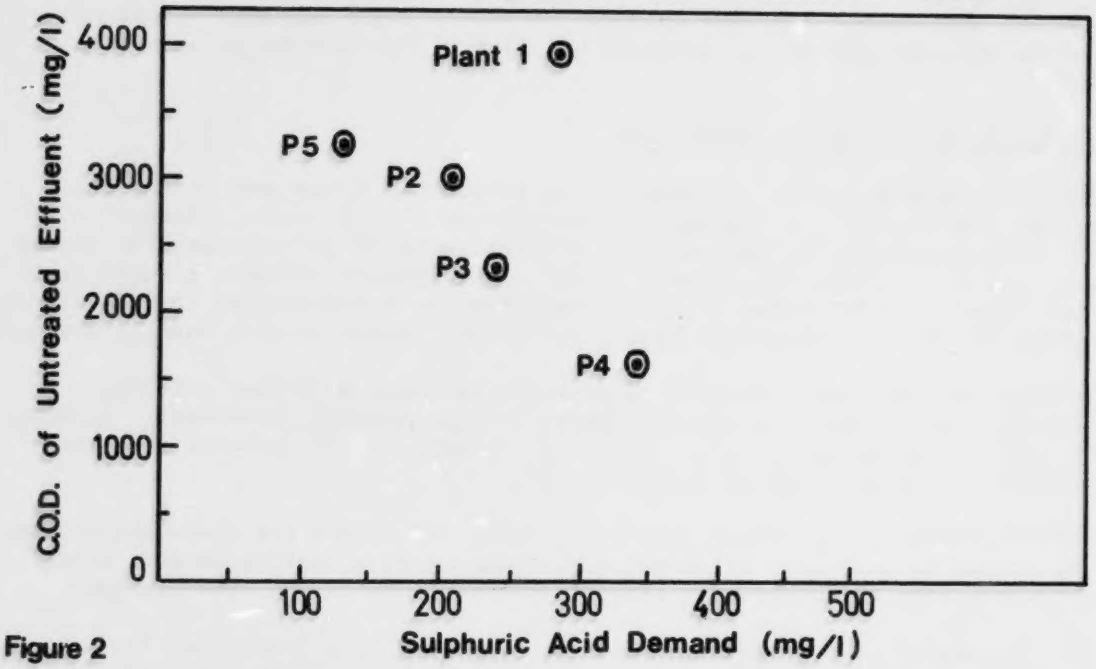
TABLE 4. TYPICAL UTILITY CHARGES* FOR THE TREATMENT OF A MEAT PACKING PLANT WASTEWATER (4500 m^3/day) AS DISCHARGED FROM A SAVEALL SYSTEM

Utility	Approx. Usage per m^3 of Effluent Treated	Unit Cost	Treatment Cost ($/m^3)
Labour		$ 3.00/hr	0.015
Oil		$ 110/tonne	0.027
Steam		$ 9.20/1000 kg	0.009
Electricity		$0.021/kWH	0.007
		Total Cost ($/m^3)	0.058
		($/1000 U.S. gal)	0.22

*Typical utility charges in New Zealand as at April 1976.

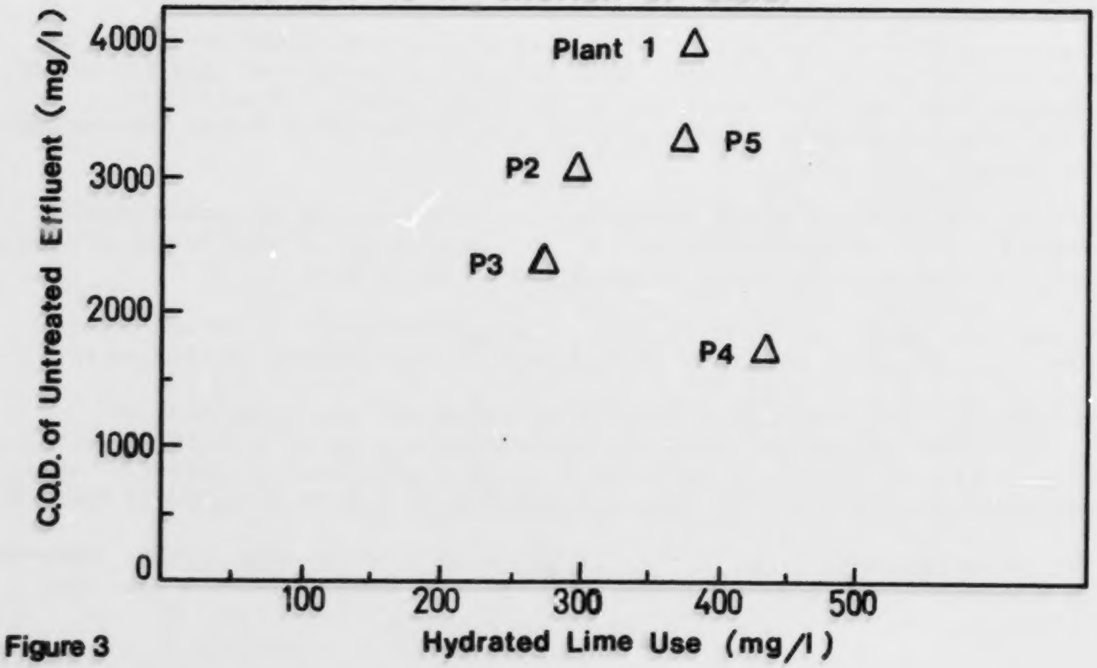
BY-PRODUCT RECOVERY

The recovery and handling of solids is an important feature of any waste water treatment scheme as in the majority of processes 40-60% of the capital



ACID DEMAND TO ACIDIFY UNTREATED MEAT PACKING PLANT EFFLUENT TO pH 3.0 AS A FUNCTION OF C.O.D.

Figure 2



LIME USAGE TO NEUTRALIZE ACIDIFIED EFFLUENT TO pH 9.0 AS A FUNCTION OF C.O.D.

Figure 3

investment is involved. This aspect is especially significant to a process in which the recovered by-product is saleable and utilized to offset treatment operating costs. For these reasons considerable emphasis in the overall process development has been extended to evaluating a suitable method of solids recovery and to the nutritional value of the product as an animal feed.

Sludge Conditioning and Dewatering

The basic aim of sludge treatment is to reduce the volume and render the sludge inoffensive for disposal or recovery as a by-product. Sludge conditioning refers to chemical and physical methods for altering the sludge properties to permit the release of water. In general organic sludges require some form of conditioning prior to dewatering to transform the characteristic amorphous gel-like structure into a porous mass which is more readily dewatered.

In this process heat treatment is employed to break down this gel-like structure and permit dewatering without further chemical treatment. A change in particle structure results due to the coagulation of proteins and the release of a proportion of unbound grease.

Heat treatment is by direct steam injection. To reduce the steam requirement the sludge is initially thickened and preheated in a heat exchanger, using hot water from the dewatering stage to recover most of the sensible heat.

The coagulated sludge is then partially dewatered in a horizontal bowl decanting centrifuge with continuous solids discharge. The bowl and conveyor speeds, and the pond depth are chosen so as to optimize solids recovery and cake moisture content.

The composition of effluent to be treated will determine the percentage of free fat present in the sludge. When heated a proportion of this fat may be rendered and leave the centrifuge in the liquid phase. If sufficient quantities are present economic recovery may be justified before the centrate is recycled.

For by-product recovery the discharged centrifuge solids are pneumatically dried to approximately 92-93% solids. A short residence time in the pneumatic dryer ensures minimum thermal degradation of the product.

By way of example the pilot scale dewatering of a sludge recovered after treatment of a meat packing plant effluent by this process is discussed:-

Thickened sludge recovered after sedimentation was heat coagulated at 103-105°C for approx. 1 minute before passing directly to a 15 cm diameter horizontal bowl decanting centrifuge. Optimum centrifuge differential speed and pond depth consistently produced performance data as outlined in Table 5.

The centrifuge cake solids were particulate in form and were further dewatered in a pneumatic dryer to achieve a final moisture content of less than 7%.

TABLE 5. CENTRIFUGE PERFORMANCE IN DEWATERING SLUDGE RECOVERED AFTER CHEMICAL TREATMENT OF MEAT PACKING PLANT EFFLUENT

Parameter	Level Recorded
Sludge Flow (l/min)	20
Input Settleable Solids (%)	4
Centrifuge Cake Solids Content (%)	40
Centrate Settleable Solids (%)	0.3
Centrate Floatable Grease (%)	1.3
Settleable Solids Recovery (%)	92

By-Product Use as an Animal Feed

Clearly the value of any recovered by-product as an animal feed will in part depend on the composition of the effluent treated.

By comparison with many present meat meal feed materials the recovered by-product is generally low in protein and high in total grease content. For this reason the product is used as a dietary supplement for non ruminant animals, being incorporated in the feed at apportioned levels, often ranging between 5-15% inclusion. For this application the by-product grease content may be used in place of tallow, often added to feeds to improve the metabolic efficiency. ME/CP (Metabolisable Energy/Crude Proteins).

Comparison of supplements from the treatment of meat packing plant effluents with that of a typical meat and bone meal show that the ranges for crude protein, total grease, and ash content on a dry basis are as follows:

Component	Effluent Supplement	Meat and Bone Meal
Crude Protein (Nx6.25)	20-35%	45-55%
Ash	20-35%	10-20%
Total Grease	20-40%	5-15%

The range reflects the variation between effluent from different meat packing plants and the seasonal variations within a plant. Analyses also indicate sufficient concentrations of essential amino acids such as lysine and tryptophan for the feeding of these materials to hogs and poultry.

In the main broiler chicken feeding trials have been used to assess the nutritive value of the effluent by-product. Compared to hog feeding trials these have allowed for more extensive evaluations with the limited material available. It was also considered chickens in broiler feed trials would be more susceptible to diet inadequacies than many other species.

A recent trial by the Poultry Research Centre in New Zealand to test the feeding value of meat packing plant effluent by-product meal when fed to broiler grower chickens showed that the Effluent Supplement resulted in comparable growth to similar inclusions of Meat and Bone Meal (containing 50% crude protein). The effluent meal used in this trial had a nutrient composition on a dry wt. basis as follows:

Crude Protein (Nx6.25)(%)	30.0
Ash (%)	29.8
Total Grease (%)	30.0

The effluent meal and meat and bone meal supplements were individually incorporated in separate diets with levels of inclusion ranging from 0-14%. The broiler grower chicks were randomised over 74 quad boxes with 7 males and 7 females per box, and placed in tiered electrically heated battery brooders. Evaluation of the results and an analysis of variance showed the effluent by-product produced greater weight gain than the equivalent inclusion of meat and bone meal over the three week growth period and that the rate of weight gain to food consumed was similar for both diets. These results are shown in Figure 4. The conversion of feed to body weight increased with increasing inclusion for both diets and this is attributed to an improved ME/CP ratio. No toxicity or palatability problems were encountered and in a separate trial the effluent meal ash concentration (dry wt. basis: 43.6% Ca, 15% P) was found to have no significant effect on growth for ash inclusions in the total diet varying from 0-8%.

It was concluded the effluent by-product can perform as well as a meat and bone meal and could be a useful dietary supplement in poultry rations and hog diets. Results indicate a market value (April 1976) of approx. $(N.Z.) 90-100/tonne may be acceptable for a meal of this composition.

FULL SCALE PLANT DESIGN

Process performance has been consistent through the development stages of laboratoty, pilot plant and full scale plant operation. A comparison of laboratory and pilot plant results for the treatment of meat packing plant effluent as discharged from a saveall is summarized in Table 6 and Figure 5. Pilot plant operations treated 4 m^3/hr of effluent as shown schematically in Figure 1, with the by-product being recovered for poultry feeding trials.

The only large scale application to date has been a plant treating 110 m^3/d of effluent from a poultry processing operation. Pilot scale studies on the treatment of meat packing plant effluent have led to preliminary full scale plant design for a treatment plant to process 4500 m^3/d of effluent with the recovery of some 8 tonnes of dried by-product per day. Typical costs (April 1976) for a plant to treat this volume of effluent and produce a dry bagged by-product are in the range of $(N.Z.) 700,000-800,000.

In general the economic viability of such a plant is dependent on specific plant locality and circumstances. However in one instance, for a specified

CONVERSION OF FOOD TO BODY WT. GAIN FOR EFFLUENT MEAL AND MEAT & BONE MEAL FOR P.R.C. POULTRY FEEDING TRIAL

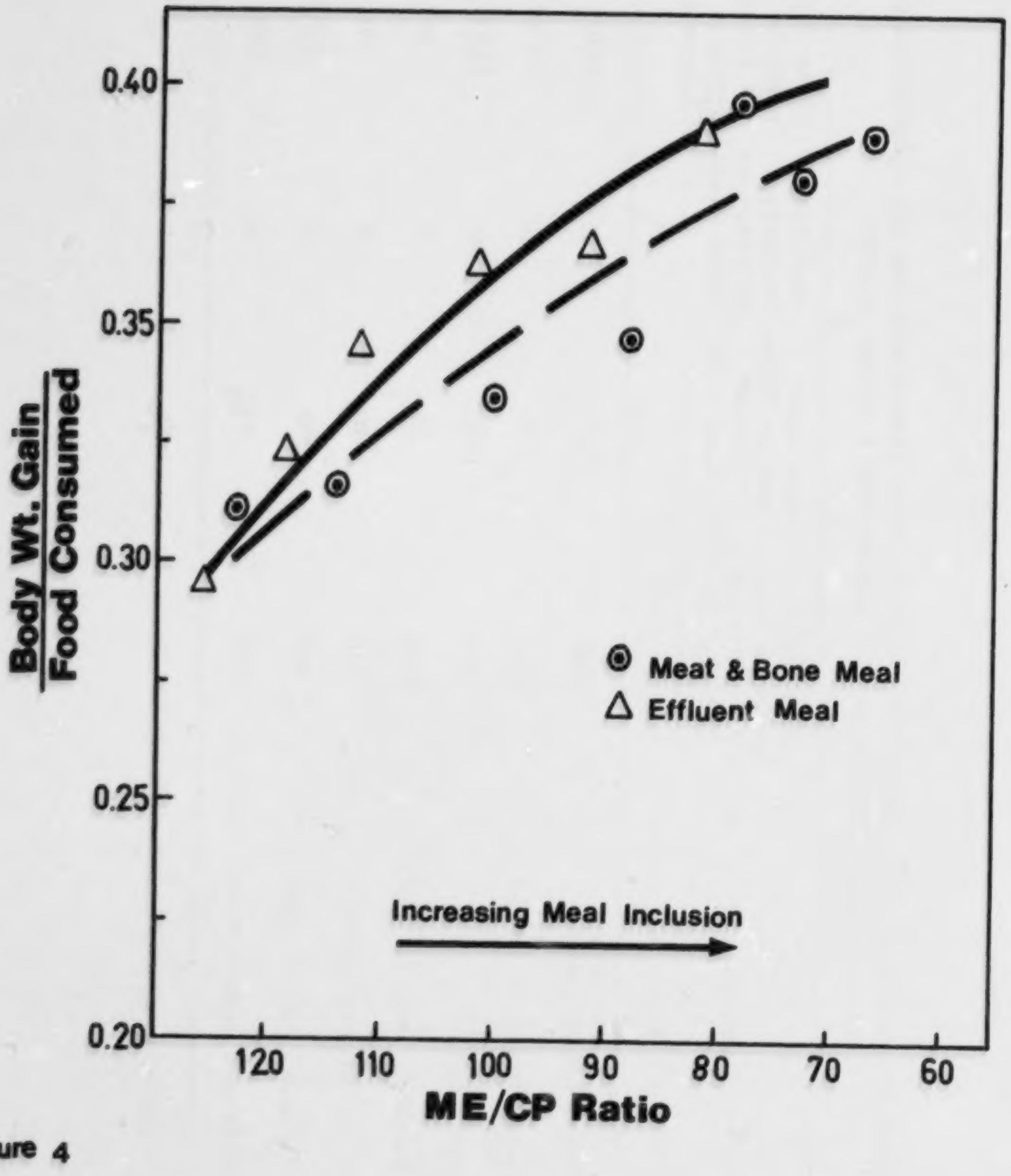


Figure 4

TABLE 6. COMPARISON OF LABORATORY AND PILOT PLANT PERFORMANCE FOR THE CHEMICAL TREATMENT OF A MEAT PACKING PLANT EFFLUENT AS DISCHARGED FROM A SAVEALL SYSTEM

Effluent Component$^+$	Mean Daily Composite Value of Untreated Effluent to Laboratory and Pilot Plant	Mean Daily Composite Value of Treated Effluent from Pilot Plant	Mean Daily Percentage Reduction on Pilot Plant	Mean Daily Composite Value of Treated Effluent from Laboratory	Mean Daily Percentage Reduction In Laboratory
Total Solids (mg/1)	2480	2070	15	1980	20
Total Organics (mg/1)	1630	450	72	550	66
Ash (mg/1)	850	1620	+91	1430	+68
Suspended Solids (mg/1)	1400	70	95	30	98
Total Grease (mg/1)	310	20	94	20	94
Protein (Nx6.25) (mg/1)	940	390	59	430	54
Chemical Oxygen Demand (mg/1)	1340	260	81	220	84

+ Analyses as per Standard Methods (2)

COMPARATIVE REDUCTION IN TOTAL ORGANICS OF MEAT PACKING PLANT EFFLUENT ON THE PILOT PLANT AND IN THE LABORATORY

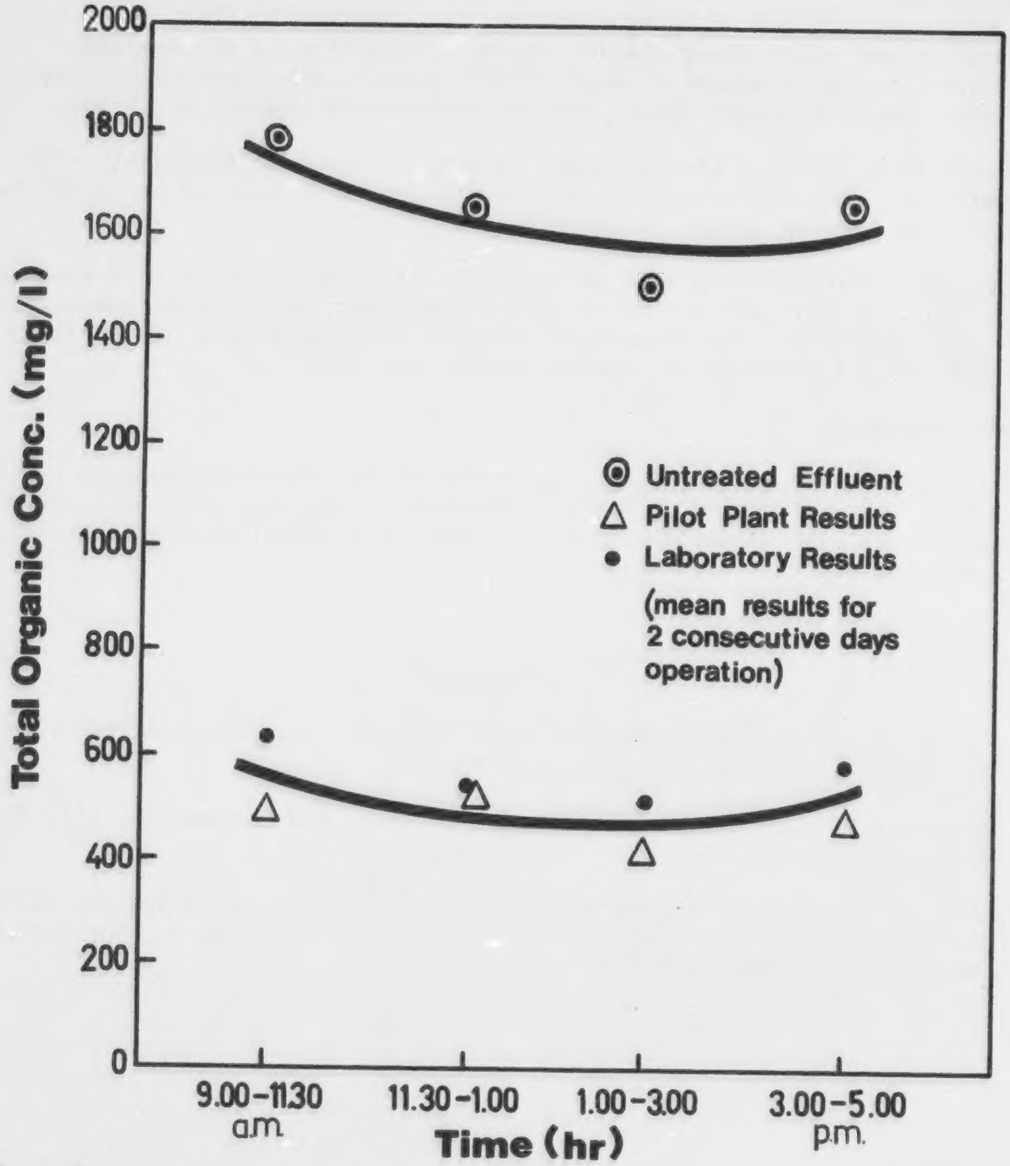


Figure 5

reduction in effluent 5-day Biochemical Oxygen Demand (BOD_5) of 70%, the capital cost was comparable with that for a biological trickling filter scheme and considerably cheaper than for an ocean outfall. Operating costs for the chemical treatment plant were higher than both of the other schemes, however the chemical treatment process did break even relative to the biological process if $50-60 (N.Z., 1976) per tonne was obtained for the by-product. Any higher values of the by-productwould indicate the chemical process to be economically superior to the biological.

CONCLUSIONS

Laboratory and pilot plant studies on the application of the process described to the treatment of meat packing plant wastes have shown that effluent chemical oxygen demand may be consistently reduced by 75-80%.

The nutritive value of the recovered by-product compared favourably with conventional meat and bone meal supplements for inclusions of up to 14% in the diet of broiler grower chickens.

The process described may meet operating costs through the sale of by-products and offer a significant return on capital depending on effluent composition and plant locality: for example in an urban area where land availability is limited and water supply and sewage charges are high.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the financial and technical support of the N.Z. Meat Industry, the N.Z. Poultry Research Centre, the N.Z. Development Finance Corp., and in particular the efforts of Bill Wakelin and Eric Retter of Morrison,Cooper and Partners.

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WASTEWATER TREATMENT AND REUSE
IN AN INDEPENDENT RENDERING COMPANY

by

William R. Isherwood* and Jack McVaugh**

INTRODUCTION

In June 1975, SARS (South Alabama Rendering Company) of Loxley, Alabama, received an NPDES permit requiring effluent modification of the plant's existing discharge into a local river. By March 1977, SARS completed and began operating a wastewater treatment system. This treatment facility adequately reduces the contaminant levels and provides a method by which the treated effluent can be recycled through the rendering process.

Simplicity of operation and recycling are major system achievements, and are considered to be the main topics of this thesis.

Simple operation is a key consideration to the success of a well-functioning plant, and allows less sophisticated, and thus less expensive, operator qualifications to be set. As was the case at SARS, no new personnel were required, and actual plant operation was reduced to routine mechanical maintenance of several new pumps and a blower.

Wastewater contaminant reduction is accomplished at SARS by biological action in an earthen lagoon system. This treatment system is designed to produce an effluent of such high quality that this effluent can be partially or totally reused as condenser cooling water. Presently, the entire effluent flow, 190,000 gpd, is being reused for cooling purposes, with the remaining wastewater introduced to the treatment system being lost through evaporation or lagoon leakage. At the prevailing treated effluent contaminant levels, however, the system could discharge over 70,000 gpd without exceeding NPDES permit levels. 100% recycling has been maintained for over nine months with complete satisfaction. Thus, daily discharge is zero. Biological degradation reduces organic contaminant levels in excess of 95%.

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*Ponder Engineering and Survey Company, Daphne, Alabama
**Envirex, Inc., Waukesha, Wisconsin

The 1976 NPDES requirements were clearly met, and thus far the future requirement--total waste discharge elimination--has also been achieved.

Of secondary interest, SARS has undertaken a pilot project by stocking the aerobic polishing pond (part of the biological system) with catfish. The fish are doing well and certainly contribute to the biological reduction of the BOD introduced into the pond. More will be said of this later in the text.

RENDERING PLANT AND OPERATION

SARS, Inc., located near Loxley in Baldwin County, Alabama, is an experienced, well-established rendering company, constructed in 1954.

SARS operates a batch rendering process to produce quality greases and tallow as well as dry "meat meal." These products are rendered chiefly from slaughterhouse waste and restaurant meat scraps and grease, and sometimes fish scraps. The processed greases are used for such products as feed, soap, lubricants, cosmetics, and cement additives, while meat meal is used almost exclusively as a protein source for animal feed, such as poultry feed and dry dog food.

The plant layout includes several buildings which enclose the entire rendering process, plus an office building, personnel locker room and shower head, boiler room, and maintenance building.

SARS rendering process is not unusual. Raw materials are trucked to the plant daily and rendered into marketable products. The plant operates five days each week, with daily operation beginning in the early evening and lasting into the next morning. Average process time is 13 hours.

The first steps of the rendering process begin when the collection trucks arrive in the afternoon. Scraps and grease are unloaded and weighed, and solid raw materials are ground. Both the ground solids and grease are then conveyed to the cooking room.

Cooking is accomplished in three large steam-heated ovens. Each oven is individually loaded and sealed. Cooking begins and automated stirring continues for about 2-1/2 hours per load, or until the moisture content being monitored is sufficiently reduced. After cooking, the renderings are removed from the ovens and strained. Grease is separated from solid material and stored, but the solids are further processed by screw expellers, producing dry meat meal and more grease. The dry meat meal is then milled into a coarse powder. Both the meat meal and grease are stored onsite in larger tanks.

PLANT WASTE

The plant is located on the headwaters of the Fish River, which offers easily attainable non-potable water and a convenient waste carryoff. SARS' rendering process requires a 550 to 750 lpm (145 to 200 gpm) cooling water supply which circulates through the barometric-leg condensers. This cooling water is virtually free of contamination.

The main contaminating waste source is from washing of floors and equipment after each day's operation. Spillage during truck unloading and grinding is unavoidable. Much of this spillage can be reclaimed by dry clean up measures, but always there is some grease, paunch manure, various solids and small quantities of blood that can only be efficiently removed by washing into conveniently-located floor drains. Slight spills and accumulated deposits are washed daily from the cooking and finishing areas, and these are also collected by the floor drains.

Figure 1 shows the original sewerage system before modification. As shown in Figure 1, a network of sewerage carried the wash water through two small grease separators where grease is hand-skimmed and returned to the rendering process. After passing these small separators, the wash water combined with one-pass cooling water at the head of the large, 75 m^3 (20,000 gallon) grease separator.

This separator, shown in Figure 2, and its operations deserve some comment. By daily hand-skimming, the effluent grease levels averaged 40 mg/1. The floating material recovery was 600 - 1200 lpd (165 - 330 gpd).

The contamination in the effluent was certainly not a grease problem. However, relatively large quantities of suspended solids contributed to biological oxygen demand and turbidity, and SARS was definitely in need of some sort of abatement process to control the contaminated effluent.

Table 1 lists the NPDES limitations set for SARS. The limitations, established by the EPA, were based on a national average, and were particularly evaluated for each rendering company on the basis of total pounds of raw materials processed daily.

Upon issuance of the permit, it was immediately obvious to SARS that their daily wastewater discharge need be reduced, or else a treatment system be installed capable of producing effluent BOD_5 and TSS concentrations less than 10 mg/1. Realizing the difficulty of the latter method, and noting the production levels of the SARS plant, the Alabama Water Improvement Commission suggested that an average discharge of 400 m^3/day (100,000 gpd) should not be an unrealistic goal. The design effluent BOD_5 goal was thus approximately 15 mg/1. Data presented in Table 2 indicated that the discharge flow had to be reduced by 33-50%. This was to be accomplished by recycle of treated effluent for cooling purposes.

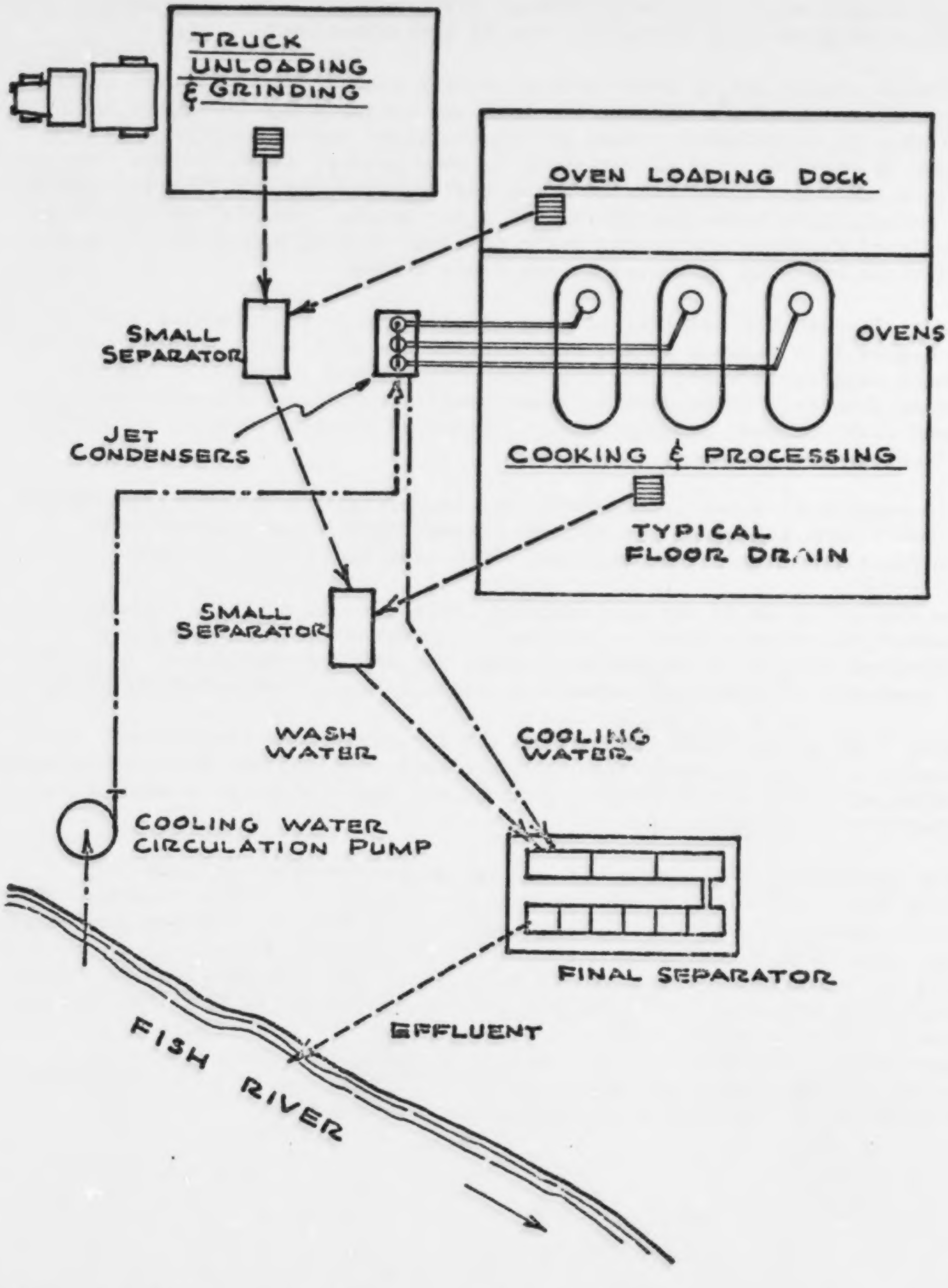

Figure 1. SARS rendering plant layout, showing original sewerage system.

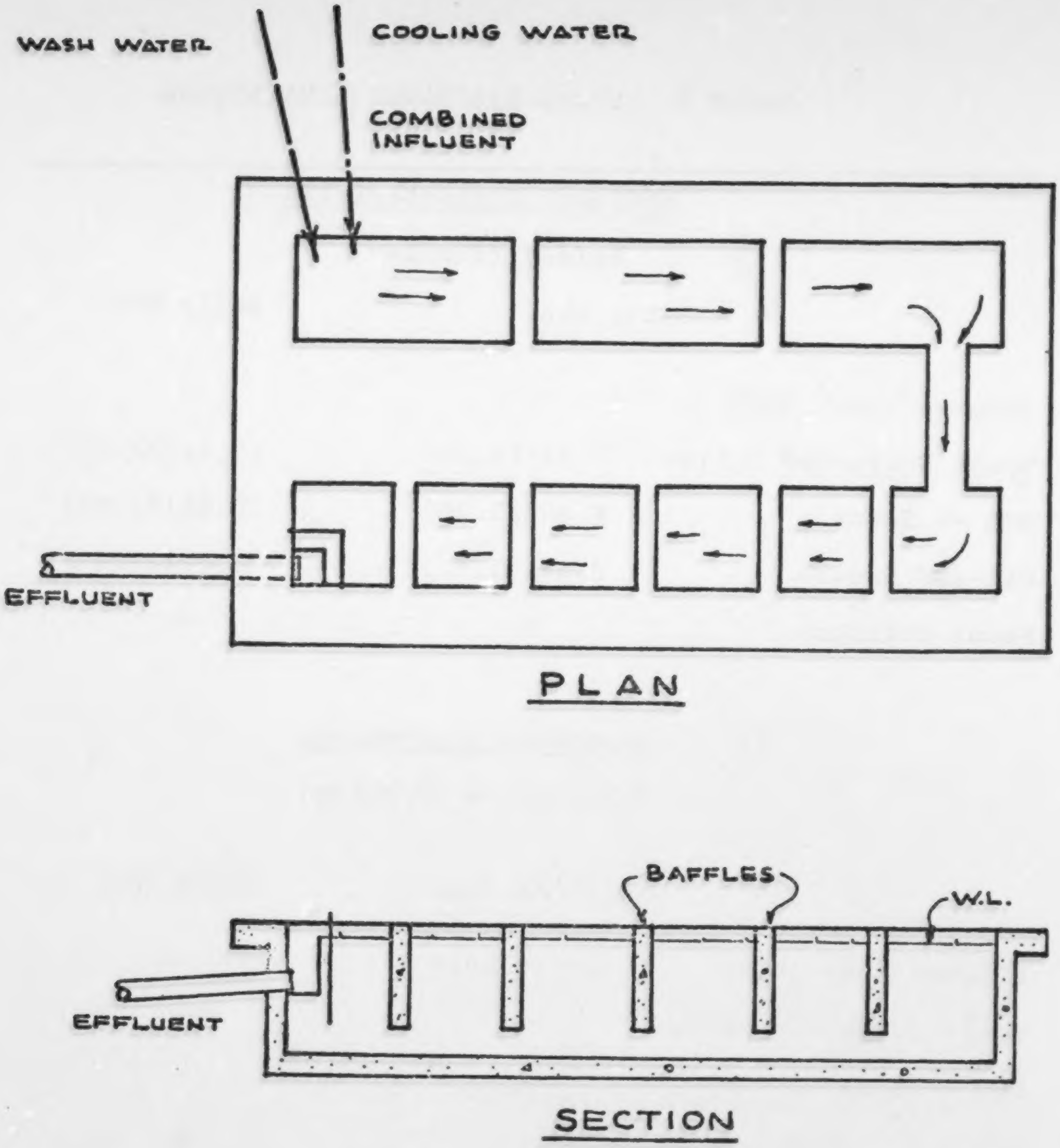

Figure 2. Final separator accomplishing 95% or better grease removal.

TABLE 1. NPDES DISCHARGE LIMITATIONS

Effluent Characteristic kg/day (lbs/day)	Daily Avg.	Daily Max
Flow--m^3/Day (MGD)	--	--
Total Suspended Solids	7.43(16.38)	14.86(32.76)
BOD -- 5-Day	6.02(13.26)	12.03(26.52)
Oil and Grease	3.54(7.8)	7.08(15.6)
Fecal Coliform	--	--

Discharge Limitations Other Units (Specify)	Daily Avg.	Daily Max
Flow--m^3/Day (MGD)	400(0.10)*	--
Total Suspended Solids	--	--
BOD -- 5-Day	--	--
Oil and Grease	--	--
Fecal Coliform	200/100ml*	400/100ml

*Alabama Water Improvement Commission Recommendation

TABLE 2. 5-DAY DISCHARGE ANALYSIS

Characteristic Analyzed	Date Samples Taken (1975)					Cooling Water Grab Sample mg/l
	Composite Effluent Concentration mg/l					
	8/12	8/13	8/14	8/15	8/16	8/16
Flow-m^3/Day	553	595	727	667	557	--
(MGD)	(0.15)	(0.16)	(0.20)	(0.18)	(0.15)	
Total Suspended Solids	45	143	56	97	91	9
BOD -- 5-Day	56	263	117	225	88	2
Oil and Grease	12	48	16	45	34	1
Fecal Coliform (1000's)	430	930	2,400	4,600	2,400	1.5

WASTE TREATMENT

After evaluating the effluent, a table of flows and concentrations was developed for treatment process design purposes (Table 3).

The maximum total daily flow was set at 795 m^3/day (0.21 MGD) by taking the maximum flow recorded and adding about 10%. Then, by measuring the cooling flow alone, both the cooling water and the wash water flows were determined.

It should be pointed out at this time that BOD and TSS were taken as the main design parameters. This is because of the nature of SARS's waste. Being organic and readily biologically degradable, it was felt that an aerated lagoon would efficiently reduce BOD, followed by a polishing pond to provide further BOD reduction and a place for solids to settle out.

Suspended solids in the wash water are mostly organic and make up a large part of the BOD. The organic or volatile solids are aerobically converted to non-degradable residue in the aerated lagoon.

TABLE 3. DESIGN FLOWS AND CONCENTRATIONS

Influent Characteristic	Quantity
Flow-m^3/Day (MGD)	
A. Total	795 (.21)
B. Cooling Water	720 (.19)
C. Wash Water	75 (.02)
Total Suspended Solids	
A. Cooling Water	$<$ 10
B. Wash Water	1225
BOD -- 5-Day mg/l	
A. Cooling Water	$<$ 10
B. Wash Water	2250
Oil and Grease	
A. Cooling Water	$<$ 10
B. Wash Water	800

As shown in Figure 3, the original primary treated effluent was the combination of cooling water and wash water flowing from the final separator. As was mentioned earlier, the total discharge had to be reduced. The decision was made to recirculate, as cooling water, some or all of the potential discharge after treating to remove organic contamination.

The Implemented Plan

Reduction of organics was accomplished by isolating the wash water from the cooling water and treating both individually. Since the wash water has such a high BOD concentration (2250 mg/l), it is treated in two biological stages. The cooling water, on the other hand, is normally very low in BOD and TSS, and needs only to be cooled somewhat to be good for recirculation. The cooling water is, however, potentially contaminated if the ovens are overloaded, causing a boilover into the cooling system which must be caught and treated.

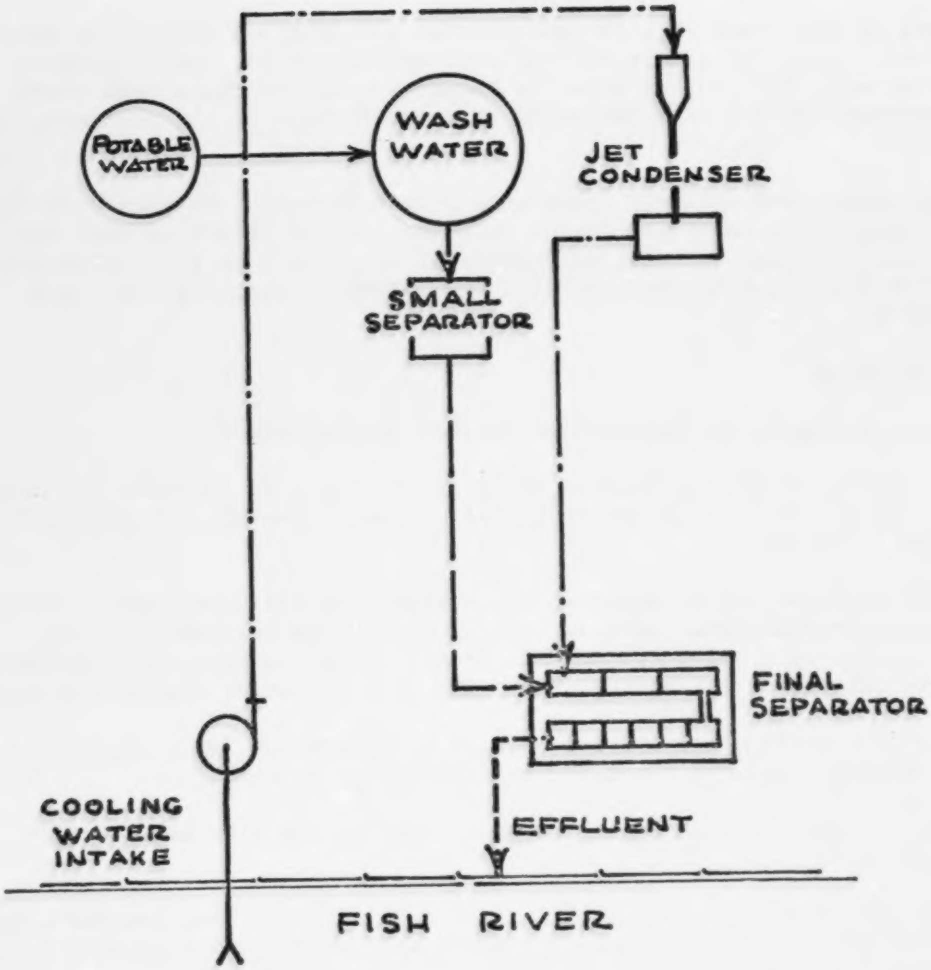

Figure 3. SARS' original flow pattern.
Cooling water and wash water combined.

Figure 4 shows the implemented plan. The wash water was segregated from the cooling water just before entering the original final separator. A new separator was constructed to remove grease from the segregated wash water flow, and is also hand skimmed. From the separator, the wash water is pumped to an earthen aeration basin.

The cooling water was left to pass through the original evaporator which serves as a trap for grease if oven overloading occurs. After passing the separator, the cooling water is pumped to the polishing pond where it combines with the aeration basin effluent to make up the polishing basin effluent.

The polishing pond effluent flows to a 5-foot diameter, 10-foot deep sump, where pumps force recirculation as coolant. If the return is ever too great for recycling, it will automatically overflow into a chlorination basin for disinfection and then will be allowed to discharge into the Fish River.

Aeration Basin

The aeration basin was required to provide the following:

1. A minimum of 90% BOD removal which is necessary to minimize the size of the polishing pond and to assure adequate removal, satisfying the NPDES limitations.

2. Sufficient volume to equalize the normally sporadic influent. Though the daily wash water flow is only 75 m^3 (20,000 gallons) per day, this flow is realized in only 10 hours. Also, pumping the wash water into the aeration basin causes severe flow variation during this period.

3. Simple operation, which is a primary consideration for a successful treatment system of the small scale required by SARS.

4. Ease of construction as an earthen basin, sealed with heavy clay material.

Considering these requirements, a basin with 20 days' retention was considered optimum. Equalization requirements were easily met with such a large retention.

Ease of construction, along with low capital cost, determined selection of the aeration device, a diffused aeration header consisting of fiberglass pipes and fittings connected by mechanical couplings. The header took approximately 12 man-hours to assemble.

Simple operation is inherent to an aerated lagoon. Operation of the aerated basin at SARS is confined strictly to routine maintenance of the blowers used in the diffused aeration system. A non-clogging, coarse-bubble diffuser was selected for aeration, eliminating the need to dewater the lagoon for periodic cleaning of diffusers. The lagoon dimensions

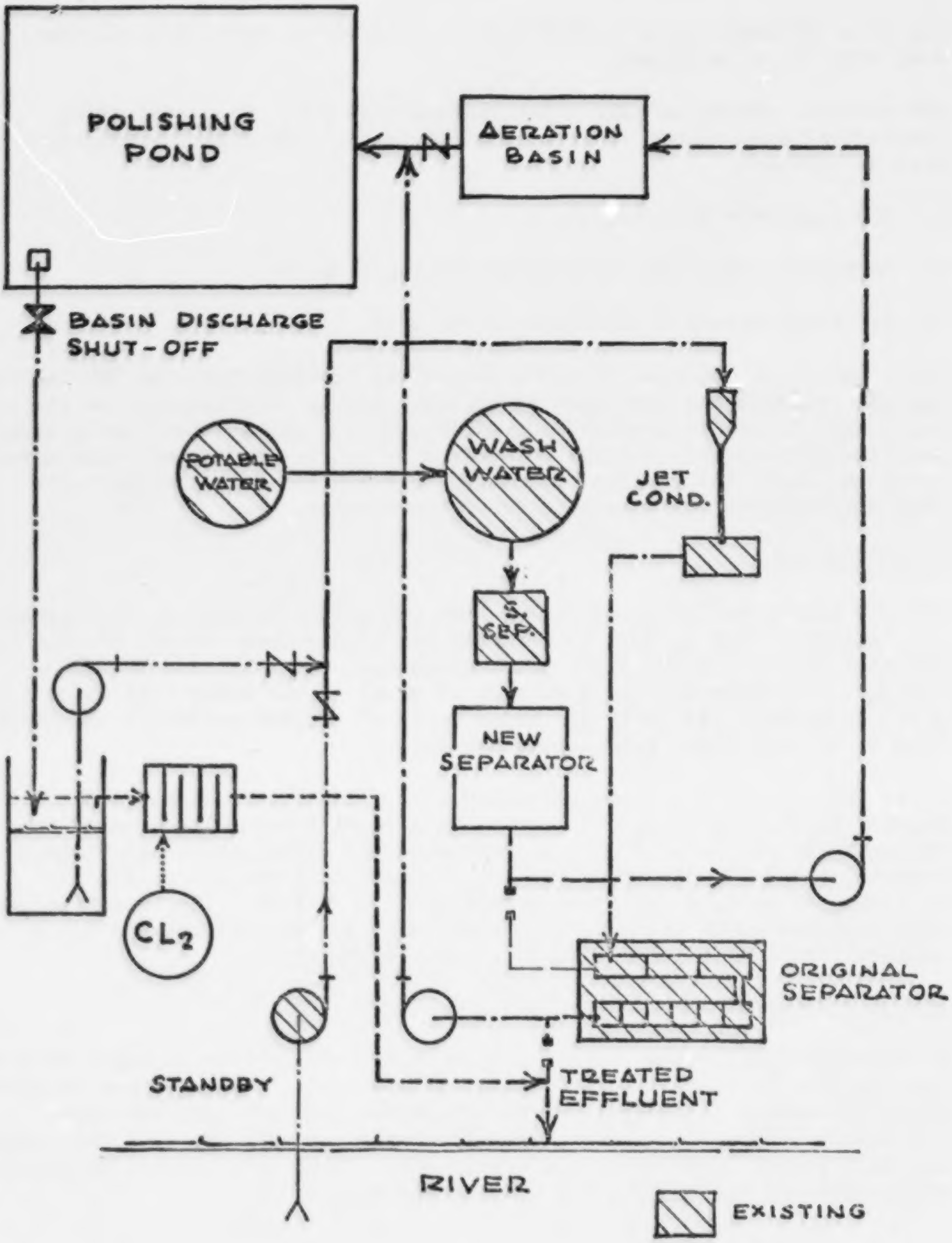

Figure 4. The implemented treatment scheme providing segregation of wash flows and cooling water.

are 12 m (40 feet) by 30 m (100 feet) at the floor, and 3.7 m (12 feet) deep with 3:1 side slopes.

BOD removal, mixing and air input requirements were calculated using theoretical assumptions in lieu of pilot tests. The design predictions were as follows:

1. BOD removal = 90 - 95%.

2. Horsepower required for complete mixing = 11.25.

3. Air requirements = 17 m^3/min. (600 cfm).

Since the plant has been in operation, it is realized that the BOD removal and air requirements have been satisfied. Mixing requirements, on the other hand, were initially greatly underestimated, but the aeration basin does function adequately. Initially intended to operate as a completely mixed aeration basin, the realized facilities operate as a facultative basin with both aerobic and anaerobic BOD decomposition.

Polishing Pond

Because SARS recycles the effluent from the polishing pond as cooling water, the retention time in days is strictly the pond volume--10,000 m^3 (2.6 MG) maximum, divided by the daily plant discharge. With no evaporation or leakage, the minimum daily discharge is equal to the daily wash water flow plus condensate. If daily discharge is 75 m^3 (20,000 gallons), the retention in the polishing pond equals 130 days.

It is anticipated that long retention will allow a very stable ecological balance in the polishing pond. This balance will assure good waste removal characteristics. Should such a long retention period prove unsatisfactory, however, the daily discharge can be increased to a maximum of 380 m^3 (0.1 MG), allowing a retention period of only 26 days. The retention can also be adjusted by changing the water level in the pond between 0.6 m (2 feet) and 2 m (6 feet) in 0.3 (1 foot) increments.

ACTUAL PERFORMANCE

In mid-March 1977, construction was sufficiently complete to begin filling the basins. By June, the first effluent was realized and as soon as possible thereafter an analysis of the polishing pond effluent was made. The results, shown in Table 4, were somewhat disappointing, but the system was very young. Suspended solids were fairly high but only due to initial disturbance of the clay sealer used in the basins.

TABLE 4. RANDOM DISCHARGE ANALYSIS

Effluent Characteristic	Date: 6/9/77	*Removal	7/27/77	*Removal
Total Suspended Solids mg/l	113	90.8%	49	96%
BOD -- 5-Day	35	98.4%	27	98.8%
Oil and Grease	1	99.9%	1.2	99.9%
Fecal Coliform 100 ml	**4,000	--	2	Excellent
pH	7	Excellent	--	--

*Removal based on design concentrations shown in Table 3, i.e., TSS - 1225 mg/l, BOD - 2250 mg/l, Oil and Grease - 800 mg/l.

**Coliform is relatively high because chlorination equipment had not been completed by this sampling date.

By mid-July, the system seemed better stabilized and another polishing pond discharge analysis was made. The results, also shown in Table 4, were more encouraging.

One effluent characteristic not included in Table 4 is daily discharge. And to this date, no discharge from the system has been required. Several times for testing and flushing purposes small discharges have been allowed; otherwise, 100% recycling has been maintained. This is due to a reduction in wash water utilization, normal evaporation, and leakage.

Because the polishing pond provided good results, SARS decided to stock it with native freshwater catfish. A thousand fingerling fry were introduced to the pond and seem to be doing well. The idea to create a well-balanced ecological equilibrium seemed incomplete without catfish, and surely they offer some assistance to the waste removal.

With no discharge, daily analysis was not required, and until mid-August, no data was recorded. Envirex, Inc., the manufacturer of the aeration equipment, offered to run an analysis consisting of three separate samplings to evaluate the treatment efficiency. Each analysis was to measure the total and soluble BOD and total suspended solids of the untreated wash water, in the aeration basins, and in the polishing pond effluent. Grab samples were taken for each day's test, but the time the samples were taken was changed to reflect various periods of the rendering schedule. The results were averaged and appear to be a fair indication of the plant's behavior, as shown in Table 5.

TABLE 5. AVERAGE TREATMENT EFFICIENCY ANALYSIS

Characteristic	Influent	Aeration Basin*	Removal	Stabilization Basin*	Removal
BOD -- 5-day mg/l	2260	305	86%	18	94%
Total Suspended Solids mg/l	3672	2411	34%	39	98%
Soluble BOD -- 5-Day mg/l	850	90	89%	--	--

	Overall Removal
BOD -- 5-Day mg/l	99.2%
Total Suspended Solids mg/l	99%
Soluble BOD -- 5-Day mg/l	--

*Effluent

To thoroughly understand SARS' or any treatment plant, samplings should be continued until trends are documented for the seasonal changes. Understandably, however, SARS is reluctant to conduct such analyses if not required by the state regulatory agency. Recycling allows SARS zero discharge and their adopted operation philosophy is as long as the system appears well, it is considered to be functioning properly.

Another point of interest is that during September of 1977 when the records of the efficiency samples were taken, it was noticed that an algae bloom was developing. Algae was, of course, prolific in the polishing pond and was anticipated. Suspended solids in the pond are mostly algae and these plants are considered advantageous in a well-balanced aquatic ecosystem.

When the bloom was first observed, it was feared that treatment efficiency might be falling off as a result, but one of the best test results was received during this period. Suspended solids were still acceptably low.

The accelerated algae growth was short-lived. Within three weeks of the initial sighting, the bloom dispersed.

ECONOMICS

The total cost incurred to implement this concept ran approximately $300,000. Continued costs to SARS for the use of the treatment facilities are the operation and maintenance for two 10-horsepower and one 3-horsepower pumping stations, and two 15-horsepower aeration blowers. Of course chlorine and maintenance of its associated equipment are a potential cost if ever utilized, in the event that discharge of treated effluent to the Fish River becomes necessary.

THE IMPACT OF THE CLEAN WATER ACT OF 1977 ON THE FOOD PROCESSING INDUSTRY

by

Carl Schafer*

A major legislative milestone in 1972 was the passage of the omnibus Federal Water Pollution Control Act Amendments, P. L. 92-500. Among its many provisions was one for midcourse corrections. After three years of study, hearings, and debate, these midcourse corrections were signed into law on December 27 as the Clean Water Act of 1977, P. L. 95-217.

The Philosophy behind the 1972 law was to "restore and maintain the chemical, physical and biological integrity of the native waters." The Law called for fishable and swimable waters by 1983 and a goal of zero discharge of pollutants into major waterways by 1985.

Instead of using water quality standards to control pollution, an approach that produced uneven results, the 1972 law shifted to a permit system. Dischargers had to limit the amount of pollutants according to Federal guidelines or "effluent limitations", that were based on the level of cleanup possible with certain technologies.

By July 1, 1977, industry was required to meet standards set using "best practicable technology (BPT)." By 1983, as new and more effective equipment was developed, the effluent limitations were to reflect the cleanup possible with the "best available technology economically available (BAT)."

The Clean Water Act of 1977 generally preserves the substantive aspects of The Federal Water Pollution Control Act (P.L. 92-500). Changes are in the nature of "fine tuning" in the area of statutory thrust. The new Act is more realistic and directs priorities towards the control of toxic pollutants.

The transition from rather broadly worded provisions in P. L. 92-500 regarding industrial point source controls, including effluent limitations, to a more realistic structure of pollutional controls was effected by definition of three characteristic groups of pollutants--each with its own regulatory and administrative requirements. Thus we now have three types of technology-based effluent control groups; toxic compounds, conventional pollutants and non-conventional pollutants.

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Toxic compounds are basically the 65 classes of toxic compounds incorporated into the new statute in Section 307 from a consent decree agreement entered into by the Environmental Protection Agency (EPA) and the Natural Resources Defense Council (NRDC). Control of these pollutants will be through effluent limitations established with "best available technology" (BAT) requirements. These effluent limitations will be promulgated by EPA no later than July 1, 1980 and they must be achieved by no later than July 1, 1984 by those classes and categories of industrial point sources identified by EPA as being subject to this requirement. There will be no economic or environmental variances granted from BAT effluent limitations and effluent standards for "toxic" pollutants.

For the present, the types of industry concerned with toxic pollutants are the 21 "heavy" industry categories covered by the consent agreement. Food processing industry categories are not now specifically affected by this program. However, sampling of food processing plant effluents for possible toxic components is an important part of EPA's research program in the area of industrial wastewater treatment.

Pollutants of essential interest to the food processing industry are those that fall under the new category of conventional pollutants. The pollutants include biochemical oxygen demand (BOD), suspended solids (TSS), pH, fecal coliform and potentially others in the "traditional" sense as may be defined by the Aministrator pursuant to Section 309.

Technology-based limitations are still required; however, a new level of technology is to be defined for establishing limits for these pollutants; namely, "best conventional pollutant control technology" or BCT. This technology requirement has been defined by the Congress to include the technical factors originally used to define BPT and BAT requirement, but with a new "cost test."

The cost test is comprised of two essentially interrelated factors: (1) reasonableness of the relation between the cost and the effluent reduction benefits; and (2) comparison of the industry category or subcategory cost and associated pollutant reduction for publicly owned treatment works.

The cost test is to be applied to any forthcoming future regulations establishing limitations for conventional pollutants. Thus, for example, (with resources permitting) regulations not previously finalized in industries such as poultry processing, miscellaneous food specialities, beverages, edible oils, and others would be finalized as BCT regulations.

In addition, the statute requires the Agency to review the "old" BAT limitations for conventional pollutants for the industries not covered by the toxic limitations program. These industries (so called "secondary industries" as a term to differentiate them from the heavy "primary industries") include all of the food processing categories and subcategories for which BAT limitations were promulgated and in effect at the time of passage of the Clean Water Act. Specific food industries covered in this review are all subcategories of the fruits and vegetables, meat products, seafoods, dairy, sugar, and grain mill processing industries.

A brief description of the review process may be helpful. The secondary industry review involves some 14 industry categories and over 200 subcategories. All data as to costs, level of pollutant reduction and specific limitations requirements were assembled and reviewed. Initial review focused on defining the population of subcategories for which the "cost test" must be performed. Thus, for example, about half the subcategories for which BPT was zero discharge or where BPT and BAT requirements were equal were screened out of the review. Coincident with this screening process, costs and performance relating to POTW control of conventional pollutants were compiled. Cost comparisons were made on an incremental basis, i.e. the cost and pollutant reduction going from BPT to BAT for industry vs. the POTW counterpart going from average (or good) secondary treatment to best secondary treatment.

Section 301 requires classes and categories of industrial point sources discharging "conventional" pollutants to achieve by not later than July 1, 1984, effluent limitations requiring application of BCT to be defined by EPA. Again, there will be no economic or environmental variances granted from BCT effluent limitations for conventional pollutants.

The third group of pollutants are those which are not specifically listed as either "toxic" or "conventional" and are therefore termed "non-conventional." These pollutants are to be regulated by BAT level technology standards. Section 301 (b) requires category and classes of industrial point sources which discharge other than toxic or conventional pollutants to achieve BAT by July 1, 1984 or within three years after promulgation by EPA, but in no case later than July 1, 1987.

In contrast to requirements for conventional and toxic pollutants, owners or operators are entitled to apply for a waiver from the BAT requirements for "non-conventional" by one or both of two mechanisms: (1) Section 301 (c) which allows waivers based upon economic circumstances (affordability) of the permittee while at least BPT is achieved; and (2) Section 301 (g) which allows for waivers based upon environmental considerations among which are that (a) water quality standards are being achieved, (b) if a waiver is granted, no other point source will have to upgrade treatment to compensate for the waived requirements, and (c) at least BPT is being met. In addition, it should be pointed out that the compliance date for toxic pollutants can be extended to July 1, 1987 if the facility is going to employ an innovative production process or new treatment technology which will result in a greater effluent reduction than required or significantly lower costs for reaching the required reduction.

Although the provisions of the new law relative to effluent limitations are of major interest to the food processing industry, there are other features of the Act which are also of interest to this industry. In regard to industrial cost recovery (ICR) payments, EPA is required to study the efficiency of, and the need for, such payments. This study is to include, but is not limited to, an analysis of the impact of ICR payments on rural communities and on industries in economically distressed areas or areas of high unemployment. The study is to be completed and submitted to the

Congress within twelve (12) months after December 27, 1977. In addition, Section 204 (b) allows POTW managers to reduce the amount of ICR payments where an industrial user reduces its total flow of sewage or unnecessary water consumption. This section also exempts from ICR requirements those industries discharging 25,000 gallons or less per day into municipal treatment plants as long as the effluent does not contain toxic chemicals or other materials that would contaminate or reduce the utility of the resulting sludge.

The Act specifically defines irrigation return flows and their cumulative effects as non-point sources. Further, the Department of Agriculture is authorized to establish and administer a cost sharing program to assist farm owners and operators to install and maintain measures necessary for control of non-point sources of water pollution. Grants may not exceed 50 percent of approved non-point source pollutant abatement measures.

Industrial direct discharge plants unable to meet the July 1, 1977 date for compliance with best practicable technology (BPT) because of contemplated future discharge into a POTW may submit a request to appropriate NPDES permit issuing authorities for extensions of time (but no later than July 1, 1983). Time extensions up to April 1, 1979 may be granted by NPDES permit-issuing officials to industrial plants not contemplating discharge into POTW's if it is found that the discharger has acted in "good faith" and if facilities necessary to comply with the BPT requirements are under construction.

EPA is required (by the Act) to conduct a study of the effect of the disposal of seafood processing wastewaters into marine waters. The study is to examine the geographical, hydrological and biological characteristics of marine waste-waters into which such wastes are discharged. In addition, the study is to examine technology which may be used to facilitate the use of nutrients in seafood processing waste waters or which may be used to reduce the discharge of such wastes. The result of the study is to be submitted to the Congress no later than January 1, 1979.

Although it was not incorporated into the final version of the Act, the legislative conference report directed the Administrator to conduct a study to be completed by January 1979 to ascertain if there is merit to argument that some Virgin Islands and Purerto Rico rum distillers might safely dispose of certain natural wastes untreated into the marine environment. In this study the Administrator should specifically examine geographical, hydrological and biological characteristics of marine waters receiving such wastes to determine if the discharge can be environmentally acceptable either for the purpose of aquaculture or some other purpose. In addition, the study should examine technologies which might be used in these industries to facilitate the utilization of the valuable nutrients in these wastes or the reduction in the discharge to the marine environment.

I have tried to discuss the provisions of the new law which will have the most impact on the food processing industry. In general, the new law stresses innovative, alternate wastewater treatment technology (recycling and reuse of wastewater including sludge, land treatment, and methods to decrease wastewater volume) with an emphasis on the importance of controlling toxic pollutants. I would like to take this opportunity to encourage each of you to carefully review the new act and EPA's proposals for implementation and to provide us with comments on those aspects you feel are appropriate.

THE APPLICATION OF DEEP SHAFT TECHNOLOGY TO THE TREATMENT OF FOOD PROCESSING WASTEWATER

by

D.S. Sandford, P.Eng.* and T. Gallo, P.Eng.**

INTRODUCTION

The Deep Shaft Effluent Treatment System is a high rate activated sludge process. It was developed by Imperial Chemical Industries in Great Britain in co-operation with various ICI subsidiaries around the world. The responsibility for the development of the technology in North America rests with Canadian Industries Limited, (CIL), through their wholly owned subsidiary, Eco Research Ltd. of Montreal, Quebec, Canada. Marketing of the technology in the United States is the responsibility of CIL-Chemicals, Inc. of Detroit, Michigan, also a subsidiary of CIL.

The North American version of the technolgoy features the Deep Shaft concept for aeration but utilizes flotation as an effective method of solids separation rather than conventional gravity sedimentation.

Initial work involving flotation as a method of achieving reliable suspended solids separation was demonstrated at Emlichheim, W.Germany where a Deep Shaft roughing treatment plant was built to treat potato processing wastewater for the KSH Company(1).

The Deep Shaft Effluent Treatment System is proving to be highly effective for the treatment of high strength readily biodegradable wastewaters which are normally found in the food processing industry.

The Deep Shaft Effluent Treatment System has also been successfully applied to the secondary treatment of municipal and industrial domestic blends of wastewater(2)(3)(4). North America's first full-scale autonomous Deep Shaft plant is currently under construction at the Town of Virden, Manitoba and is designed to treat the entire town's wastewater (ie. 5,000 population equivalent).

Several technical articles will be presented in the next twelve months regarding the operation of a Canadian Deep Shaft demonstration plant that has successfully treated brewery wastewater(5)(6).

Anheuser-Busch, Inc. of St. Louis, Missouri will be one of the first American corporations to pilot Deep Shaft technology. The Deep Shaft pilot plant at Anheuser-Busch in Williamsburg, Virginia will start-up in early April 1978.

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Interest in the technology is growing in all sectors of the food processing industry, as industrial surcharges and land values increase.

This paper should provide an overview of the operation of a Deep Shaft demonstration plant which has treated brewery wastewater at Molson Breweries of Canada Limited at Barrie, Ontario, Canada and a pilot plant operating on dairy waste for the Co-operative Agricole de Granby, Notre Dame du Bon Conseil, Quebec, Canada.

The information collected in the course of this work enables us to develop, with a high degree of confidence, cost estimates and designs for full-scale brewery and dairy applications.

PROCESS DESCRIPTION

Coarse screening and grit removal are normally the only forms of pretreatment which proceed the Deep Shaft Effluent Treatment System. Primary clarification is not required in advance of the Deep Shaft bioreactor. Aeration takes place in a totally cased and grouted shaft 100 - 250 metres (300 - 800 feet) in depth, which is divided into a downcomer and riser section by a partition or a concentric tube arrangement. The wastewater is circulated around the shaft using the airlift principle. As the circulating mixed liquor in the shaft reaches the surface, the entrained air bubbles are allowed to escape and a portion of the flow is fed by gravity to a flotation cell for solids separation while the remainder of the flow is recycled back to the shaft.

The advantages of the Deep Shaft bioreactor arise from the geometric configuration of the shaft.

As the injected air in the downcomer is entrained in the downward flowing wastewater, it experiences an increase in hydrostatic head resulting in dramatically improved oxygen transfer due to increased oxygen solubility in the lower regions of the shaft. This results in a more complete and effective oxygen penetration into the floc. Thus, oxygen utilization by the biota becomes the limiting process rather than the transfer of oxygen to the biota as in conventional systems.

The healthy physiological environment created in the bioreactor for the biota appears to result in a considerably higher kinetic rate than in conventional activated sludge systems. Therefore, Deep Shaft bioreactors tend to be extremely small in volume when compared to conventional systems.

The air that is added to the bioreactor to supply oxygen to the biota also provides the driving force for hydraulic circulation and suspended solids separation in a flotation cell following the Deep Shaft bioreactor. These are the major reasons for the exceptional power economy attained by the system.

The increased dissolved oxygen in the bioreactor, coupled with high turbulence, results in a highly aerobic, well oxygenated biomass and prevents the development of filamentous organisms. The turbulence in the bioreactor tends to comminute filaments, resulting in short, easily separable fragments.

The plug-flow nature of the shaft, preceded by complete mix circulation at the top of the shaft, is effective in diluting influent BOD_5 and reducing pH shock loads.

The metabolic cycle of the biomass in the Deep Shaft bioreactor, the result of plug-flow mode of operation, may be responsible for the lower sludge production experienced in Deep Shaft plants when compared to other high rate activated sludge systems.

The subsurface placement of the shaft and the large recirculation volume ensures a near constant temperature in the shaft all year round which is of particular importance in extreme climates.

Since the Deep Shaft Effluent Treatment System is highly aerobic, there are no putrescent odors. This, coupled with the small surface area requirements of the technology, allow plants to be totally enclosed resulting in a very favorable working environment.

The flotation mode of suspended solids separation is significant since:

(a) A reduction is possible in the size of suspended solids separation equipment because the rise rates in a Deep Shaft flotation cell are 3-4 times that of conventional clarifier settling rates.

(b) The efficient use of readily available dissolved gas allows a high concentration of mixed liquor suspended solids to be separated efficiently.

(c) Floating sludge is thickened to 4-8% in the flotation cell eliminating the need for sludge thickening equipment and the associated energy costs.

Figure 1 and 2 illustrate the process schematics used to demonstrate the viability of the Deep Shaft Process to treat dairy and brewery wastewater respectively.

DAIRY WASTEWATER TREATMENT

Wastewater from the cheese and powdered milk producing plant of the Co-operative Agricole de Granby at Notre Dame du Bon Conseil, Quebec, Canada has been successfully treated using the Deep Shaft Effluent Treatment System. The pilot plant consisted of an 20 cm x 157 m (8" I.D. x 500') deep shaft containing a 6.76 cm (2.66") I.D. U-tube bioreactor. Solids separation was accomplished in a separate cell following the bioreactor.

The results of the pilot plant study provide the design criteria enabling Eco to design full-scale Deep Shaft dairy wastewater plants. Figure 1 shows the schematic of the plant.

As the full-scale plant is expected to operate at higher than ambient temperature, provision was made for controlled heating of a water jacket.

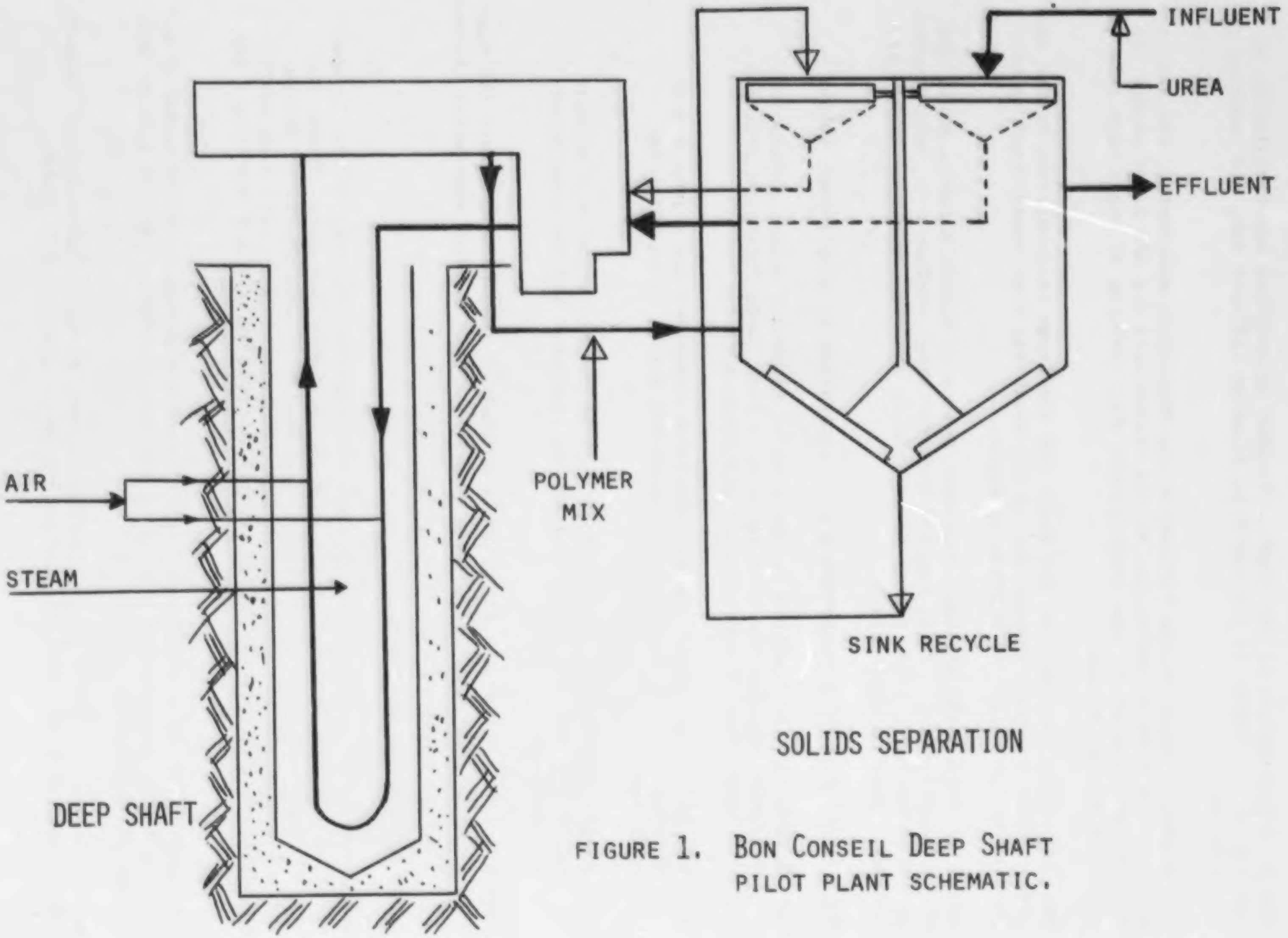
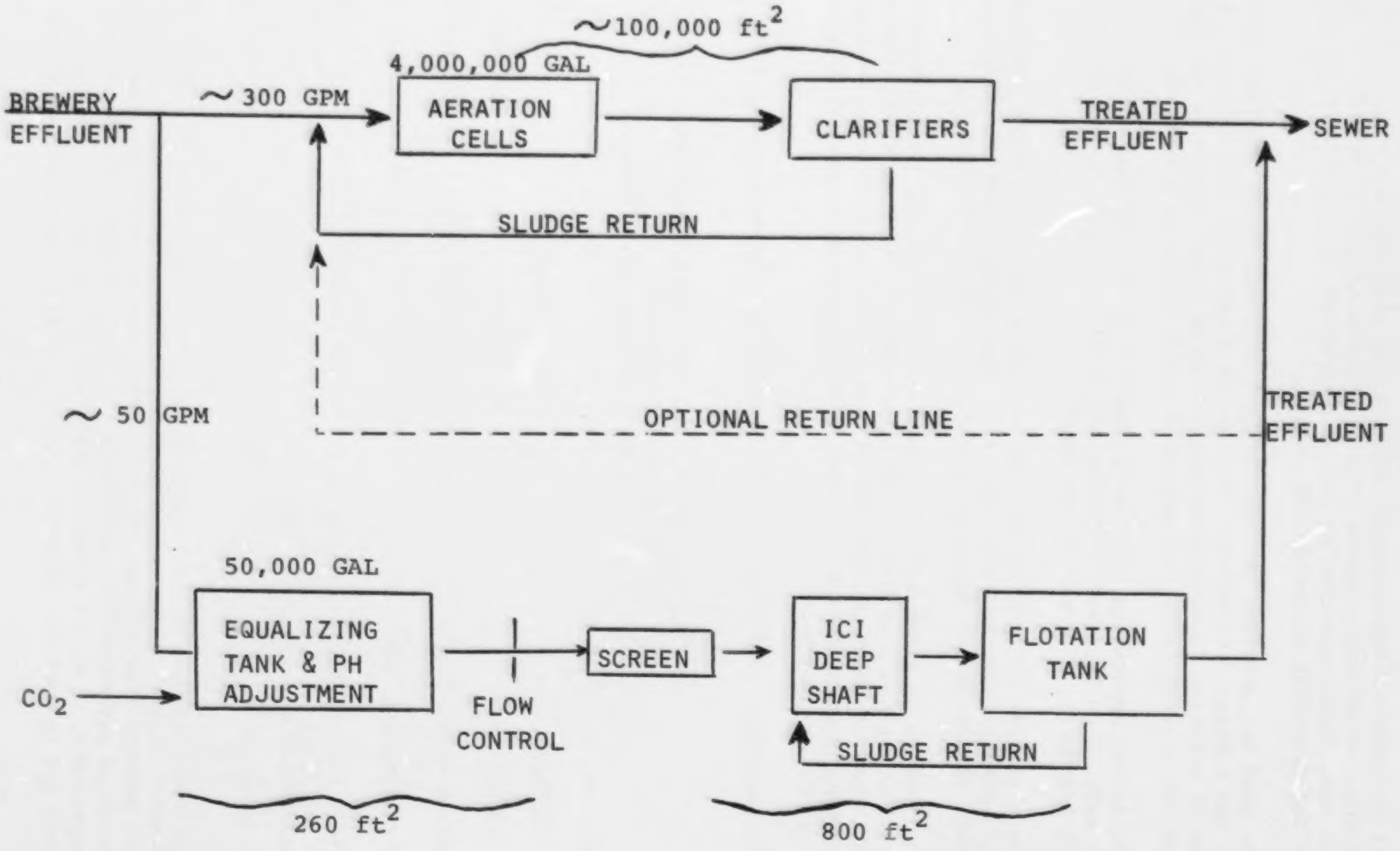


FIGURE 1. BON CONSEIL DEEP SHAFT PILOT PLANT SCHEMATIC.

FIGURE 2. MOLSONS DEEP SHAFT DEMONSTRATION PLANT
BARRIE, ONTARIO, CANADA.



Air is added to the downcomer side of the shaft as a source of biological oxygen. Pilot scale shafts require additional air to maintain circulation and this can be provided by adding airlift on the riser side of the shaft or by the provision of mechanical pumping.

The head box provides the free surface area necessary to allow disengagement of gas bubbles. Dissolved gases in the riser side of the shaft slowly come out of solution forming microscopic bubbles which attach to the flocs, creating the driving force for suspended solids separation by flotation.

The solids separation tank is cylindrical with a conical bottom. Provision is made to collect both floating and settled solids. Collected bottom and top solids are returned to the shaft.

The shaft was drilled in February and March of 1977 and the plant was ready for commissioning in early May 1977. The objective was to define the Deep Shaft operating and design parameters for dairy treatment.

The results on a one week intensely monitored period, as presented below, were undertaken from October 25 to November 1, 1977 at which time the plant was operated continuously with 24 hour per day supervision. Various streams were analyzed including influent, mixed liquor, effluent and wasted sludge at 1 or 2 hour intervals.

The operating conditions for the test period are outlined in Table 1.

TABLE 1. BON CONSEIL DEEP SHAFT PILOT PLANT
OPERATING PARAMETERS
SEVEN DAY INTENSIVE TEST PERIOD

Parameter	Metric	USA
Feed Rate	8.74 ± .08 m^3/hr.	0.5 ± 0.05 USGPM
Bottom Recycle Rate	8.74 m^3/hour	0.5 USGPM
Air Injection Rate	8.5 N m^3/hr @ 690 KN/m^2	5 SCFM @ 100 psig
Mixed Liquor Temperature	32°C	90°F
Mixed Liquor Suspended Solids	5,000 mg/l	5,000 mg/l

In late November 1977 a series of tests were conducted on a feed prepared by dissolving dry whey powder in tap water and feeding this to the shaft, allowing drastic fluctuations in the loading resulting in variable sludge ages and changing physiological conditions. During the last period of this two week experiment, alum was added to determine its effects on overriding fluctuating load and to improve effluent clarity. Drastic improvements in the floating behavior of the sludge occurred, providing alum was added to the shaft at a concentration of 1 mg of trivalent aluminum/gram of MLSS. The suspended solids concentration in the effluent was reduced to a level averaging 49 mg/l in 24 hour composites during the final six days of the tests. Since these values were obtained on dissolved whey powder, normal dairy wastewater should result in better sludge characteristics and solids separation.

Sludge production has been measured to be 0.5 kg of sludge/kg of BOD treated. Consideration has been given to suspended solids escaping in the effluent.

Healthy microflora included bacteria of diverse morphology (ie. cocci, bacilli, long thin rods and occasionally fragments of filaments). Protozoa present in the healthy sludge include colonies of Opercularia and active Vorticella. No visible difference in the diversity of the microflora was observed whether dairy waste or whey was being treated. The flocs produced by artificial whey influent looked more open and fragile than flocs produced by dairy feed.

Filamentous organisms often plague conventional dairy waste treatment plants, however filamentous bacteria were only observed on rare occasions when the shaft did not receive adequate oxygen for reasons of foaming or organic overloading. No filamentous bacteria occurred after excess oxygen was provided to take care of all load conditions.

Provision was made for continuous monitoring and control of pH of the mixed liquor. It became evident that the mixed liquor was naturally buffered between a pH of 6.9 and 7.6. No additional acid or alkali was required to keep the pH in this range, although the client's record of raw dairy effluent pH showed a dramatic fluctuation between 2 and 12.

Discussion of Process Behavior During Seven Day Intensive Study

Results of Seven Day Intensive Study

Table 2 outlines the results of the seven day intensive study conducted between October 25 to November 1, 1977.

The results of the seven day intensive study indicate that an effluent of less than 150 mg/l suspended solids can be attained without the use of coagulant aids.

Throughout the seven day intensive study, the load fluctuated sharply over a twenty-fold increase in conventional F/M (ie. 0.18 - 3.2 days^{-1}) without upsetting the substrate removal efficiency or solids separation efficiency of the system. A sudden change in waste characteristics (ie. whole dairy waste to whey) may require several hours of biomass acclimatization, however equalization should reduce this impact.

All components in the influent appeared to be treated, in fact butter fat actually aids flotation while milk proteins cause foaming in the head tank which can be easily controlled with a mechanical foam breaker.

TABLE 2. BON CONSEIL DEEP SHAFT PILOT PLANT SEVEN DAY INTENSIVE STUDY PERIOD PERFORMANCE

Parameter	Influent (mg/l)	Effluent (mg/l)	Removal Efficiency (%)
Total BOD_5	1597[a]	125[b,c]	98.3
Total SS	498	138	72.3
FOG	388	76	80.4

Note: (a) BOD_5/COD ratio = 0.7

(b) Filtered BOD_5 = 25 mg/l

(c) Filtered COD = 181 mg/l

Changes in the nature of the waste (ie. milk to whey) during the test period required several hours of acclimatization, however some relief from large and rapid variations in waste characteristics for full-scale plants can be buffered with an acceptable degree of equalization.

Full-Scale Deep Shaft Dairy Plant Cost Estimate

Table 3 describes the influent of a 64 m^3/hr. (0.4 mgdUSA) full-scale Deep Shaft plant to treat high strength dairy wastewater to 50 mg/l BOD_5 and 50 mg/l TSS specifications.

TABLE 3. DEEP SHAFT DAIRY PLANT COST EXAMPLE WASTE CHARACTERISTICS AND TREATMENT

Equalized Daily Flow	64 m^3/hr. (0.4 mgd USA)
Total BOD_5	2400 mg/l ± 30% fluctuation
Effluent TSS and BOD_5	50 mg/l
Population Equivalent	38,000 people

Table 4 describes the design parameters and capital cost for the full-scale dairy Deep Shaft plant. The Deep Shaft portion of the plant offers excellent space economy. It is estimated that a 64 m^3/hr. Deep Shaft plant would require less than 344 m^2 (3,700 ft^2) to enclose including preliminary treatment and solids handling.

The power economy for the Deep Shaft plant is estimated at three times that of a conventional plant. The power economy for Deep Shaft plants is estimated at 3.6 kg O_2 transferred/kWh.

A sludge concentration of 5% by weight due to the thickening in the flotation cells reduces sludge handling and disposal costs when compared to conventional systems using sedimentation which produces solids prior to dewatering or stabilization at 1-2% concentration.

TABLE 4. DEEP SHAFT DAIRY PLANT COST EXAMPLE

	Metric	U.S.A.
Shaft Dimensions	1.6 m x 250 m	63" I.D. x 800'
Plant Surface Area	350 m^2	3700 ft^2
MLVSS	6500 mg/l	6500 mg/l
Sludge Production	$\frac{\text{0.5 kg dry solids}}{\text{kg BOD}_5\text{ removed}}$	$\frac{\text{0.5 lbs dry solids}}{\text{lb BOD}_5\text{ removed}}$
Waste Sludge Concentration	5%	5%
Energy	109 kW	145 HP
Oxygen Transfer	9,409 kg O_2/day	20,700 lbs O_2/day
Power Economy	3.6 kg O_2/kWh	5.95 lbs O_2/HP-hr.
Capital Cost	$1.5 million	$1.5 million

The operating costs for the plant are outlined in Table 5. An aeration cost of 4.7¢/m^3 (17¢/1,000 gallons USA) of wastewater treated can be derived from Table 5.

TABLE 5. DEEP SHAFT DAIRY PLANT COST EXAMPLE

Operating Cost/Yr.	
Manpower[1]	10,000
Energy[2]	25,000
Chemicals[3]	1,000
Sludge Disposal[4]	60,000
Maintenance[5]	7,500
Nutrients[6]	7,000
	$110,500

Operating Cost Assumptions

1. Manpower based on ½ day attendance/day.
2. Energy based on $233/kWh ($175/HP/yr.).
3. Chemicals based on alum @ 1 mg Al^{+++}/g MLSS.
4. Sludge disposal based on $0.27/metric ton-km hauling costs, assuming 16 km transport.
5. Maintenance based on ½ of one percent of capital cost.
6. Nitrogen required at 100:10:1.

BREWERY WASTEWATER TREATMENT

A Deep Shaft demonstration plant was constructed in 1976 at Molson's Brewery in Barrie, Ontario, Canada to investigate the potential for the process to treat brewery wastewater and to develop design information to allow full-scale brewery Deep Shaft Effluent Treatment plants to be built. Molson Breweries of Canada Limited were attracted to the Deep Shaft Process in view of potential savings in land, potentially less sludge for disposal and the apparent energy savings that the technology offers. A schematic of the existing wastewater treatment plant is shown in Figure 2. The existing extended aeration effluent treatment plant at Molsons has been very effective in meeting the existing 300 mg/l BOD_5 and 350 mg/l TSS pretreatment guidelines established by the City of Barrie.

Operating experience has shown that the Molson's Deep Shaft can be effectively used for biological treatment and sludge thickening or digestion of waste activated sludge from the extended aeration plant.

The Deep Shaft hardware at Barrie is considerably different that the U-tube pilot plant at Notre Dame du Bon Conseil, in that the Molson's Barrie plant is a prototype. The shaft consists of an 0.46 metre (18") I.D. steel casing 157 metres (510') deep grouted in a drilled hole 0.62 metres (24") I.D. Following the Deep Shaft headworks, a rectangular flotation cell receives partially degassed effluent. The flotation cell has a top and bottom rake and scraper arrangement. The effluent from a flotation cell passes over an adjustable effluent weir.

Molsons provide approximately 9,042 m^3 (62,500 USG) of surge tank capacity in view of influent hydraulic and organic load fluctuations.

The ratio by weight of BOD_5 to ammonia, nitrogen and orthophosphate was 100:.31:.22. It was determined eventually that this situation created a nutrient deficient biological condition in the shaft and resulted in unpredictable sludge behavior detrimental to the performance of the Deep Shaft Process. Urea and phosphoric acid were added to bring the BOD to nitrogen to phosphorous ratio to an acceptable level of 100:8.7:1.3 during the thirty-one day August/September 1977 evaluation period. It has been established that approximately half of the nutrients are bioavailable in the effluent and therefore only half of this value will have to be added. Therefore, for the purpose of cost estimates, the nutrient addition requirement of 2.5 kg of ammonia, nitrogen and 0.5 kg of orthophosphoric acid are required for 100 kg of BOD_5 in the influent.

Pretreatment consists of screening which removes particles in excess of 0.64 cm (¼") in diameter.

The plant was commissioned in October 1976, however it was not until August of 1977 after several developmental modifications that the plant could be properly evaluated as a BOD and TSS removal system.

One basic difference between the Deep Shaft and extended aeration plant was in the nature of the sludge. There were never filamentous organisms in the Deep Shaft sludge which was in complete contrast to the extended aeration sludge. The Deep Shaft sludge contains many types of protozoa including stalked ciliates, which are indicative of a healthy biomass culture. Specific oxygen uptake rates were measured and were found to be in the range of 8-20 mg/g/hr.

The Deep Shaft plant at Barrie was operated in the flotation mode for six months and the BOD_5 and TSS removal was within the City of Barrie industrial bylaw effuent specifications of 300 mg/l BOD_5 and 350 mg/l TSS.

The existing Deep Shaft mechanical configuration has not operated optimally in a flotation mode for mechanical reasons; however, all parties involved are in agreement that solids separation by means of flotation is entirely feasible.

Modifications planned for April of 1978 will correct this problem resulting in excellent flotation. The results of a 31 day intensive study evaluation period presented herein are based on the flotation cell operating successfully in a clarifier mode. Reliable flotation has been demonstrated at the Paris, Ontario Deep Shaft demonstration plant and at Emlichheim, W.Germany as discussed elsewhere(1)(4). Therefore, Eco is confident that excellent flotation can be achieved at the Molson's Deep Shaft plant with some minor modifications.

The successful operation of the Deep Shaft plant during the one month test period between August 18 and September 18, 1977 is presented in Table 6.

TABLE 6. MOLSONS' DEEP SHAFT DEMONSTRATION PLANT ONE MONTH TEST PERIOD(6)

Parameter	Influent (mg/l)	Effluent (mg/l)	Removal Efficiency (%)
$TBOD_5$	2624	109[(a)]	95.8
TSS	1208	257	78.7

(a) soluble effluent BOD_5 = 18

The operation parameters during the one month intensive test period are shown in Table 7.

Settling rates in the clarifier (ie. flotation cell) are up to 4 m/hr. with a stirred volume averaging 59 ml/g. The presence of aluminum in the influent originating from the bottle washing operation, accentuates the successful coagulation and flocculation that occurs.

Total excess activated sludge wasted as a result of biological treatment in the Deep Shaft system over the 31 day period, was estimated at 0.71 kg of sludge/kg of BOD_5 removed.

Power economy in the shaft was estimated at 1.7 kg of BOD_5 removed/kWh (2.8 lbs of BOD_5 removed/HP-hr.) on the average and 3.2 kg of BOD_5 removed/kWh (5.2 lbs of BOD_5 removed/HP-hr.) on peak loading. However, since an equal amount of air was being added at all times, 0.2 - 1.4 kg of BOD_5 were oxidized/kg of oxygen applied depending upon the BOD loading. This is probably due to the initial absorption of colloidal BOD_5 onto the floc which is further oxidized at a later time depending upon the sludge age. Full-scale shaft designs may include a device to vary the air delivery in accordance with changes in base line organic loading.

TABLE 7. MOLSONS' DEEP SHAFT DEMONSTRATION PLANT ONE MONTH PERIOD(6)

Operational Parameter	Metric	U.S.A.
Flow	5.73 m^3/hr.	0.036 mgd(USA)
Equalization	9,042 m^3	50,000 gallons
$TBOD_5$(in)	2624 mg/l	2624 mg/l
TSS(in)	1208 mg/l	1208 mg/l
Oxygen Transfer	500 kg/day	1100 lbs/day
Power Economy	2.8 kg O_2/kWh	4.6 lbs O_2/HP-hr.
Sludge Production	$\frac{\text{0.71 kg sludge}}{\text{kg BOD}_5\text{ removed}}$	$\frac{\text{0.71 lbs sludge}}{\text{lb BOD}_5\text{ removed}}$
Energy	7.5 kW	10 HP
Solids Concentration	3-4%	3-4%
BOD_5:N:P	100:8.7:1.3	100:8.7:1.3
MLSS	5000 ppm	5000 ppm

Proper equipment installation and energy conservation measures could increase power economics to 6 kg of BOD_5/kWh (10 lbs of BOD_5/HP-hr.) on full-scale plant designs.

It is apparent that the flotation tank operating as a clarifier can operate successfully at 8.59 m^3/hr. (37.5 US gpm) and 5,000 ppm MLSS.

The proper design of other pilot plants confirm that a proper anticipation of air loading to the shaft and consequently its effect on gas stripping should allow optimized flotation design of the Barrie Deep Shaft plant at 8.59 m^3/hr. (35 gpm) and 8,000 MLSS.

Complete equalization of the waste is not deemed necessary, even at higher F/Ms, but it is recommended that 6 hours residence time be provided at the Barrie plant.

Deep Shaft waste activated sludge stability has not been studied in detail, however while operating the shaft as an aerobic digestor over a four day period, it was observed that the specific oxygen uptake of the sludge could be reduced by 88% at a shaft temperature of 20°C. Laboratory studies indicate that a 93% reduction is possible at 25°C and this is accomplished by a 34% weight reduction to provide a sludge with only 62% MLVSS.

Preliminary indications suggest that Deep Shaft activated sludge could be dewatered to 20% solids using a filter aid, such as ferric chloride.

The Advantages of Flotation Over Sedimentation

Flotation generates 4% solids and allows mixed liquor concentrations of 1% in the shaft at a recycle rate of 50%. Sedimentation is generally limited to 1.5% settled solids at .75% mixed liquor and 100% recycle. Sludge volumes are therefore, drastically smaller when flotation is used as a method of solids separation. Subsequently, the cost of Deep Shaft systems using flotation is lower.

Flotation rise rates tend to be 3 times faster than settling rates, which results in smaller flotation cells and a reduced length of time that the biomass is outside of the shaft.

The advantages of flotation are associated with the synergistic effect of using the same air for biological aeration, hydraulic circulation and as a driving force for solids separation.

The more concentrated solids float is less expensive to process on vacuum filters or filter presses and further reduces sludge handling and disposal costs.

Economic Evaluation

A cost comparison between the Molsons' extended aeration and Deep Shaft demonstration plant is presented in Table 8. It is interesting to note that the aeration costs for the Deep Shaft plant is 4.5 times less than the aeration costs for the extended aeration plant. The cost of pH control is not included since excess carbon dioxide from the brewery process is used for pH control on the basic side of 7.

The extended aeration does not include nutrient costs, but this is probably offset by the fact that aerator usage may not be optimized.

TABLE 8. MOLSONS' DEEP SHAFT DEMONSTRATION PLANT COST COMPARISON(6)

Component	Deep Shaft ($/1,000 kg BOD_5)	Extended Aeration ($/1,000 kg BOD_5)
Aeration[1]	7.51	35.64
Nutrients[2]	7.57	undefined
Digestion	5.83	undefined
	20.91[3]	35.64

[1] Based on 30.33 kW @ 1.6¢/kWh.

[2] Based on \$4.84/1,000 kg BOD_5 (\$2.20/1,000 lbs BOD_5) for ammonia nitrogen and \$2.73/1,000 kg BOD_5 (\$1.24/1,000 lbs BOD_5) for phosphoric acid.

[3] Relates to \$1.80/1,000 m^3 (26.2¢/1,000 USG).

Full-Scale Deep Shaft Brewery Plant Cost Estimate

Table 9 describes the cost of a full-scale Deep Shaft plant designed on the basis of the design information developed at the Molson's Deep Shaft demonstration plant.

The hypothetical plant is assumed to consist of screening, comminution, grit removal, equalization, neutralization, Deep Shaft aeration, flotation, chemical addition, vacuum filtration and sludge disposal.

The Deep Shaft cost includes the installed cost of the aeration and solids separation portion of the plant assuming all front-end components are essentially equal for all biological systems. The Deep Shaft Process however, does not require primary sedimentation in advance of it.

Table 10 and 11 offers a breakdown of energy and operating costs for the two Deep Shaft options investigated. The roughing plant will, in fact, experience a large degree of BOD_5 removal but a large amount of solids would be slipped to the sewer.

The total Deep Shaft costs estimated at 2.5 and 2.75 million dollars for roughing and complete treatment are expected to represent 43 and 51% respectively of the total plant capital costs. The Deep Shaft operating costs are expected to represent 50% of the total operating cost as demonstrated in Table 11.

TABLE 9. DEEP SHAFT BREWERY APPLICATION COST EXAMPLES(6)

Parameter	Units	Duty Roughing (300/300)	 Complete (50/50)
Mean Flow	m^3/hr.	636	636
Peak Flow	m^3/hr.	700	700
Organic Loading	kg BOD_5/day	14,545	14,545
MLSS	mg/l	8,000	8,000
Energy(a)	kW	224	242
Operating Cost(b)	$/day	704.05	1,107.76
Cost/Flow	$/1,000 m^3	1.24	1.85
Deep Shaft Portion	% of total cost	43	51
Deep Shaft Cost	$ million	2.5	2.75
Deep Shaft Plant Area	m^2	743	743

TABLE 10. DEEP SHAFT BREWERY APPLICATION COST ESTIMATE

(a) Energy	Duty Roughing (300/300)	 Complete (50/50)
Deep Shaft Aeration	191.00	210.00
Lighting	6.75	6.75
Scrapers	4.50	4.50
Sludge Pumps	15.00	15.00
Fans	7.00	7.00
Instruments	0.75	0.75
TOTAL	225.00 kW	244.00 kW

TABLE 11. DEEP SHAFT BREWERY APPLICATION COST EXAMPLE

(b) Operating Cost ($/day)	Duty Roughing (300/300)	 Complete (50/50)
Energy	85.82	93.02
Chemicals/Nutrients	110.08	110.08
Flotation Aids	NIL	256.00
Manpower	108.00	108.00
Sludge Handling	263.65	356.16
Sludge Disposal	136.50	184.50
TOTAL	$704.05/day	$1,107.76/day

CONCLUSIONS

Eco has established the basic design parameters for full-scale brewery and dairy Deep Shaft effluent treatment plants.

The subsequent costs of construction and operation can be accurately projected for full-scale brewery and dairy Deep Shaft effluent treatment plants.

Full-scale Deep Shaft effluent treatment plants can now be built to treat dairy and brewery effluent to municipal pretreatment levels of 200 mg/l BOD_5 and 200 mg/l TSS and levels of 50 mg/l BOD_5 and 50 mg/l TSS for direct discharge.

Improvements in suspended solids separation should result in an ability to meet 30 mg/l TSS in the future.

The major advantages associated with utilizing the technology to treat food processing wastewater include possible reductions in capital cost, lower power costs and space economy.

The technology can be used in urban centres because it can be inexpensively enclosed and is odorless and noiseless (ie. less than 85 db).

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NINTH FOOD WASTE SYMPOSIUM
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